NUTRITIVE VALUE OF POLLOCK FISH SCALES AS DETERMINED BY RAT FEEDING TESTS

SPECIAL SCIENTIFIC REPORT—FISHERIES No. 260

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

EXPLANATORY NOTE

The series embodies results of investigations, usually of restricted scope, intended to aid or direct management or utilization practices and as guides for administrative or legislative action. It is issued in limited quantities for official use of Federal, State or cooperating agencies and in processed form for economy and to avoid delay in publication.

United States Department of the Interior, Fred A. Seaton, Secretary

Fish and Wildlife Service, Arnie J. Suomela, Commissioner

NUTRITIVE VALUE OF POLLOCK FISH SCALES AS DETERMINED BY RAT FEEDING TESTS

by

Donald G. Snyder
Biochemist

and

Hugo W. Nilson
Supervisory Chemist

Special Scientific Report--Fisheries No. 260

The Library of Congress has cataloged this publication as follows:

Snyder, Donald Graeff, 1926–
Nutritive value of pollock fish scales as determined by rat feeding tests, by Donald G. Snyder and Hugo W. Nilson. [Washington, U. S. Dept. of the Interior, Fish and Wildlife Service, 1959]

11 p. diagr. 27 cm. (U. S. Fish and Wildlife Service. Special scientific report: fisheries no. 260)

Bibliography: p. 9.

1. Scales (Fishes) I. Nilson, Hugo Waldemar, 1901– joint author. II. U. S. Fish and Wildlife Service. III. Title. (Series)

SH11.A335 no. 260 636.087 59–60216

Library of Congress

The Fish and Wildlife Service series, Special Scientific Report--Fisheries, is cataloged as follows:

U. S. *Fish and Wildlife Service.*
Special scientific report: fisheries. no. 1–
[Washington] 1949–

no. illus., maps, diagrs. 27 cm.

Supersedes in part the Service's Special scientific report.

1. Fisheries—Research.

SH11.A335 639.2072 59–60217

Library of Congress

ABSTRACT

Rat feeding studies have indicated that pollock fish scale protein is as well digested but about 30 percent less assimilated than a protein supplement consisting of 3 parts casein and 1 part lactalbumin. Fish scales as the only source of 9 percent protein in the diet are incapable of supporting growth of young rats, but the scales can be utilized as a limited source of protein when supplemented with casein-lactalbumin protein. Increased utilization of scale protein in combination with stepwise higher levels of casein-lactalbumin indicate that no toxic substances *per se* are present in scales for growing rats.

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INTRODUCTION

During the past few years, the fishing industry has been confronted with the increasingly difficult problem of annually disposing of thousands of tons of fish scales, as fillets have replaced unprocessed fresh fish in sales volume. Harbors nearby to plants normally allow for an inexpensive area of scale disposal, but unless tidal flows are strong, pollution may result.

Attempts to use the scales as fertilizer on local farms have been unsuccessful, and the incineration of scales would be costly. Chemical engineers and pharmaceutical houses have been asked for suggestions for utilizing the scales, but this approach, too, has been unsuccessful. In order to determine whether the scales may have value as a source of protein in farm-animal diets, the nutritive value and some factors affecting the nutritive value of the nitrogen compounds in whole scales are being studied.

Part of this work--rat-feeding studies to compare the nutritive values for growth, the biological values for maintenance, and the digestibilities of pollock fish scale and of casein-lactalbumin protein--is reported herein. The nitrogen content of pollock scales is equivalent to about 60 percent crude protein (N x 6.25).

Very little research has been conducted with fish scales in the past, and none has been conducted that would promise a solution to the proposed problem. For many years, however, investigators have been studying the nutritive value of similar biological materials. Meunier _et al_. (1927), Routh and Lewis (1938), and Routh (1942a, 1942b) have investigated the nutritive possibilities of wool, and Wagner and Elvehjem (1942, 1943) and Newell and Elvehjem (1947) have investigated the nutritive quality of some waste keratins. The nutritive values of meal from untreated and treated chicken feathers have been studied by Routh (1942b), Binkley and Vasak (1950), Wilder _et al_. (1955), Feedstuffs (1956), as well as others.

In general, these studies have indicated that scleroproteins are nutritionally inadequate but can be used as a partial source of protein with proper supplementation. As far as is known, no studies have been conducted to determine the feed value of fish scales, the scleroprotein now being considered.

MATERIAL AND ANALYSIS

The fish scales used in this study were kindly furnished by the staff of the Fishery Technological Laboratory, U. S. Bureau of Commercial Fisheries, East Boston, Massachusetts. Pollock (_Pollachius virens_) were scaled by hand. The scales were washed with water, drained, spread in pans, and dried in an oven at 100° C. They were shipped to this laboratory, where they were ground as finely as possible in a coffee grinder. An analysis of the particle size of a typical batch of ground scales showed that 3 percent were caught on a 20-mesh U. S. Standard screen, 19 percent on a 40-mesh, 36 percent on a 60-mesh, 18 percent on a 80-mesh, and 7 percent on a 100-mesh, and that 17 percent passed through a 100-mesh screen.

The moisture, protein (N x 6.25), fat, and ash of representative samples of scales from the various lots showed no great variation. The mean and ranges of moisture content of 4 lots of scales were 4.4 percent and 1.0-6.9 percent, respectively; of protein content of 11 lots, 59.5 percent and 56.6-62.5 percent; of fat content of 4 lots, 0.004 percent and 0.0-1.0 percent; and of ash content of 5 lots, 38.9 percent and 36.1-43.1 percent. Association of Official Agricultural Chemists (1955) methods of analyses were used.

No significant differences in the nutritive value of the scale protein were found among lots. The small differences in moisture, protein, fat, and ash contents of the scales probably can be attributed to the nutritional status and age of the fish from which the scales were collected (1954).

EXPERIMENTAL

Postweaning rats were fed diets containing a total of 9 percent protein from pollock fish scales (PFS) or a protein supplement of 3 parts casein and 1 part lactalbumin (CL)in stepwise substitution, on an equal nitrogen basis, of the PFS protein, namely, 2.25, 4.50, and 6.75 percent. In addition, the CL was also fed alone at these three levels of protein, as well as at the 9 percent level.

The basal diet had the following composition: lard, 8; cod-liver oil, 2; salt mixture U.S.P. XIV, No. 2, for vitamin-A bioassay, 4; and dextrin, 86 parts by weight. To every 100 g. of the basal diet were added 100 mg. of choline chloride, 15 mg. of alpha tocopherol, and 75 mg. of the following vitamin mixture: thiamine HCl, 1; riboflavin, 2; pyridoxine, 1; Ca pantothenate, 10; nicotinamide, 10; inositol, 5; para-aminobenzoic acid, 30; biotin, 0.05; folic acid, 0.2; menadione, 14.2; and ascorbic acid, 2 parts by weight. Vitamin B_{12} was supplied to the rats by adding 0.2 ml. of a 0.005 percent aqueous solution to individual 250 ml. water bottles every time they were refilled. The ground PFS and CL were incorporated into this basal diet at the expense of dextrin.

Four highly inbred black-hooded rats, two males and two females, were allotted to each group. The males were allotted at initial live weights of 49 to 53 and the females at 48 to 50 g. Litter-mates were randomly distributed among the various groups, but never more than one to any single group.

The rats were housed individually in wire-screen cages fitted on wire-mesh floors. The temperature of the room was maintained at 80° F. The rats were supplied with food and water ad libitum, and weekly records were taken of live weight and food consumption. The feeding study lasted 10 weeks. The apparent digestibilities of the protein consumed by individual rats were determined in aliquots of the ground, debris-free feces, collected during the fourth and fifth week of the feeding test.

Four adult male albino rats, two each fed PFS and CL protein, were used to determine the biological value for maintenance, according to the method proposed by Mitchell (1924). The rats were housed in cages on wire screens, over funnels into which a small wire screen was inserted to catch feces and allow urine to pass. Urine was collected in 600 ml. beakers under toluene, and a few ml. of a 3-percent solution of H_2SO_4 was used as additional preservative. The feces were collected from the small screens and separated from food, hair, and other debris, and were ground. Nitrogen was determined in measured aliquots of the urine and feces.

The non-nitrogenous diet fed to the rats contained: dextrin, 60; sucrose, 21; salt mixture U.S.P. XIV, No. 2 for vitamin-A bioassay, 4; lard, 13; and cod-liver oil, 2 parts by weight. To each 100 g. of this basal diet was added 0.072 and 0.240 mg. of thiamine and riboflavin, respectively. The test protein was incorporated into a 4-percent agar - 10-percent sucrose gel mixture. A 3-day precollection and a 2-day collection nonprotein-feeding period; a 3-day precollection and a 3-day collection protein-feeding period; followed by a second 3-day precollection and a 2-day collection nonprotein-feeding period was used. The quantity of test protein fed daily during the protein-feeding period was equivalent to the nitrogen contained in the urine daily during the first collection period.

RESULTS AND INTERPRETATIONS

The data in table 1 and figure 1 indicate that the male and female rats fed the diet containing 9 percent protein from PFS alone lost considerable weight and died before the eighth week of the study. The rats fed the basal diet with no added protein lost about the same weight and died at about the same time. Evidently 9 percent PFS protein did not permit growth any better than no protein added to the basal diets.

The mean gain of 135.9 g. of the group of rats fed the diet containing 9 percent CL protein, indicates that CL was more efficiently utilized than the various other 9 percent protein combinations of PFS-CL contained in the diets (table 1). The mean gain of the group of rats fed this diet at the end of 10 weeks, however, was not statistically significantly different ($p = > 0.05$) from that of the group fed the diet in which 2.25 percent PFS protein replaced a like amount of CL protein, namely, 117.5 g. Therefore, inclusions of up to 25 percent protein from PFS in place of equal amounts of CL, as the sole source of protein, and at a total level of dietary protein of 9 percent, does not adversely affect the nutritive value of the protein for growing rats. It is interesting to note that the males grew better than the females when fed the diet containing 9 percent CL protein, which would be expected, but grew similarly when fed the diet containing 2.25 percent PFS and 6.75 percent CL protein, which would not be expected, since the mean gains of the two groups were not statistically significantly different. This observation might indicate that the males and females differ in their ability to utilize the PFS protein in this combination with CL protein.

The mean weights at 10 weeks of the group of rats fed the diets containing 6.75 percent PFS and 2.25 percent CL protein (15.3 g.) and 4.50 percent CL protein alone (23.8 g.) also were not statistically significantly different ($p \geq 0.05$). All of the mean weights of the groups of rats fed the other diets were statistically significantly different ($p \leq 0.01$) for the 10-week period. The coefficients of variation generally were smaller than usual for this type of a feeding study (9 - 12 percent).

Although the group of rats fed the diet containing 9 percent PFS protein alone died, the different groups of rats grew increasingly better when they were fed diets in which 2.25, 4.50, and 6.75 percent of this PFS protein was replaced by equal amounts of CL protein. This increased growth was apparently directly correlated with the stepwise higher levels of CL protein in relation to PFS protein in the diet. However, the rats fed diets containing these increasing levels of CL protein alone in the diet did not grow as well as rats fed these same diets containing, in addition, the decreasing levels of PFS protein to make a total of 9 percent protein. This added growth with PFS protein indicates that the PFS protein certainly was being utilized.

An increase of 31 g. in mean gain was obtained when the group of rats was fed the diet containing 6.75 percent PFS and 2.25 percent CL protein over that obtained for the group fed the diet containing 2.25 percent protein from CL alone. This increased growth cannot be the result of the added PFS protein or the low level of CL protein, since rats fed diets containing these levels alone did not gain weight. Apparently, the 2.25-percent level of CL protein was ample to balance the 6.75 percent PFS protein.

An increase of 73 g. in mean gain was obtained when the group of rats was fed the diet containing 4.50 percent PFS and 4.50 percent CL protein over that obtained from the group fed the diet containing 4.50 percent CL protein alone. This greater growth of rats fed a diet containing an even lower level of PFS protein suggests that the PFS protein was more completely balanced by the additional CL. In this case, CL protein could be used for growth when fed alone in the diet at this low level and the PFS protein might be envisioned as contributing additional nutrients.

An increase of 34 g. in mean gain was obtained when the group of rats was fed the diet containing 2.25 percent PFS and 6.75 percent CL protein over that obtained for the group fed the diet containing 6.75 percent CL protein alone. This increased growth of 34 g. is not as great as when the previous pair of diets are compared, namely, 73 g. This result is to be expected, inasmuch as there was less PFS protein in the diet and the nutritively superior CL protein was present in sufficient quantity to permit greater utilization. It is interesting to note that there was a relation of nearly 1:2:1 (31, 73, 34 g.) for the increased growth when the three pairs of diets were fed. This might indicate that the balancing values of the two proteins vary when different levels of each were included in the diets.

The data in table 1 indicate, in general, that as the rats grew better less protein was required per unit gain in weight. This decreasing requirement for protein suggests that increasing amounts of CL protein permit the rats to utilize the PFS protein more efficiently. When this index, as well as the previously compared growth rates, is used as the criteria for PFS protein utilization, trends of data indicate that no toxic substances *per se* are present in the fish scales.

The data in table 2 indicate that the mean apparent digestibility of PFS protein was about 80 percent when fed at the 9-percent level in the diet. The data also indicate that this level of digestibility was not statistically significantly increased ($p => 0.05$) when the rats were fed diets in which the CL protein was substituted in part or in whole for 9 percent PFS.

The increase in digestibility of diets containing the smaller to greater levels of CL protein alone is interesting. It may be that as the rats ingested the stepwise higher levels of food nitrogen, the residual metabolic products eliminated in the feces, as well as the digestibility of the CL protein remained equal. Hence, the ratios of ingested food nitrogen divided by the unabsorbed food nitrogen plus residual metabolic nitrogen would increase. There would be an error in calculating the digestibility of the protein for rats fed a diet containing a small amount of protein which would restrict food intake and limit growth compared with those obtained for rats fed a diet containing an adequate level of protein which would result in increased food intake.and greater growth.

Biological values for maintenance of 61.2 and 61.1 were gotten for PFS protein with two sets and, similarly, 85.3 and 89.4 were gotten for CL protein. The CL protein appears to be utilized about 30 percent more than PFS protein. True digestibilities determined in this test indicated that both PFS and CL protein were completely digested. Whereas the apparent and true digestibility of the two proteins by rats are similar, quite different assimilation is indicated by the biological values.

DISCUSSION

Investigators studying the nutritive value of other waste scleroproteins have concluded that they are nutritionally inadequate, but can be used as a partial source of protein with proper supplementation. This conclusion is also true with pollock fish scale protein.

Rats fed a diet containing 9 percent protein from PFS alone lost considerable weight and died in about 8 weeks. Rats fed diets containing PFS in combination with stepwise higher levels of CL protein, for a total dietary protein level of 9 percent, however, utilized the diet for growth increasingly better. These rats also grew better than those fed the stepwise higher levels of CL protein alone in the diet. In general, as the rats grew better they utilized the food for growth more efficiently.

Routh (1942a, 1942b), Wagner and Elvehjem (1942, 1943), Newell and Elvehjem (1947), Wilder *et al.* (1955), and others showed that the various nutritively deficient scleroproteins could be utilized or balanced with proper supplementation, but in general they did not indicate that this utilization or balance could be improved when greater levels were included in the diets. In most cases the supplementations consisted only of empirical amounts of amino acids added to the diet in order to find out which acids alone or in combination permitted better utilization of the scleroprotein.

The rats fed the diet containing a 9-percent level of protein from CL alone grew better than rats fed any other 9 percent protein combination of PFS and CL protein. At this level of protein in the diet, at least, CL protein must be better balanced in nitrogen nutrients than the protein from any of the combinations. Thus, the growth of rats fed diets containing increasing levels of PFS protein in relation to fixed levels of CL protein was less and less. Toxic factors, *per se*, in the scales must be ruled out, because there then would be no variation in the utilization of PFS protein by the rats. Furthermore, there were no visible symptoms of toxicosis.

The protein of the fish scales is digested sufficiently well so this cannot be an important factor in explaining the effects noted. The results showed that, at the 9-percent level in the diet, both PFS protein and CL protein were about 80 percent digested when fed to rats. This high level of digestion indicates that the incomplete, probably imbalanced, PFS protein had been absorbed to a considerable extent and was available for metabolism. The utilization after absorption, as shown by the biological values, is quite dissimilar, however. This difference in utilization may suggest that better assimilation of this protein, that is utilization, is responsible, at least in part, for the greater nutritive value of PFS in combination with the stepwise higher levels of CL protein. Apparently the PFS protein is more completely utilized when the higher levels of CL are fed because the protein furnished by CL supplies more and more of the lacking amino acids or other nitrogen compounds.

The problem remains as to the value of more commonly available sources of protein to supplement PFS protein as feed, and the ability of other species of animals to metabolize this protein.

SUMMARY AND CONCLUSIONS

Postweaning rats were fed diets containing pollock fish scales (PFS) or a protein supplement of 3 parts casein and 1 part lactalbumin (CL). The latter also was fed at three levels of protein in stepwise substitution of, as well as in place of, the pollock scales. Apparent digestibilities of protein by individual rats were determined in diets fed during this feeding study. The biological value for maintenance and true digestibility was determined for PFS and CL protein.

The data indicate:

1. The mean apparent digestibility is 80 percent when PFS protein is fed at a 9-percent level in the diet to male and female rats. This value of digestibility is not significantly increased ($p => 0.05$) when rats are fed diets in which the CL protein is substituted in part or in whole for the 9 percent PFS. PFS and CL protein is completely digested, as indicated by true digestibility values, when only enough is fed to equal metabolic nitrogen.

2. A level of 9 percent PFS protein as the only source of protein in an otherwise adequate diet is incapable of supporting growth in young rats. This nutritional inadequacy of PFS protein is likely due to a deficiency and/or imbalance of specific nitrogen nutrients.

3. PFS protein can be utilized by rats as a limited source of protein for growth when supplemented with CL protein in the diet. Decreasing ratios of PFS to CL protein in the diet permit progressively better utilization of the PFS protein.

4. No toxic substances *per se* are present in pollock fish scales for growing rats.

5. The biological value of PFS protein for maintaining rats is about 60 percent; which is about 30 percent less than for CL protein.

ACKNOWLEDGEMENTS

The authors wish to thank Mr. Robert Kifer for his assistance in caring for the animals, and Mrs. Sue Nealis for her assistance in the statistical analysis of the data.

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Table 1

Mean grams gain in weight, mean grams of diet consumed, and mean grams gain per gram of protein ingested for rats fed diets containing pollock fish scale protein and casein-lactalbumin protein

Diet designation	Mean gain in weight in grams			S.E.[1]	Mean grams of diet consumed			Mean grams gain per gram of protein ingested		
	male	female	male and female		male	female	male and female	male	female	male and female
PFS, 9.00%	-17.5	-15.0	-16.3	0.50	111.0	109.0	110.0	-1.76	-1.51	-1.64
PFS, 6.75%-CL, 2.25%	22.5	8.0	15.3	5.38	347.0	292.0	322.0	0.72	0.29	0.51
PFS, 4.50%-CL, 4.50%	98.5	94.5	96.5	3.52	563.5	595.5	579.5	1.95	1.76	1.86
PFS, 2.25%-CL, 6.75%	119.5	115.5	117.5	2.86	530.5	545.5	538.0	2.50	2.36	2.43
CL, 9.00%	152.7	121.5	135.9	9.17	654.3	592.8	619.1	2.59	2.27	2.40
PFS, 0.00%-CL, 0.00%	-20.5	-22.5	-21.5	1.73	96.0	104.0	100.0	-	-	-
CL, 2.25%	-15.0	-15.5	-15.3	2.69	180.0	166.0	173.0	-3.88	-4.37	-4.13
CL, 4.50%	21.5	26.0	23.8	1.65	308.5	314.0	311.3	1.56	1.84	1.70
CL, 6.75%	73.5	74.0	73.8	5.20	448.0	432.5	440.3	2.41	2.53	2.47

1/ Standard error of the mean for gain in weight at the concluding week of the feeding study.

Table 2

Mean apparent digestibility of the proteins in the diets fed to rats to compare pollock fish scale and casein-lactalbumin protein

Diet designation	Mean % apparent digestibility				
	males	females	males and females	S.E.[1]	C.V.[2]
PFS, 9.00%	83.7	75.3	79.5	2.82	7
PFS, 6.75%-CL, 2.25%	76.3	76.8	76.5	1.34	4
PFS, 4.50%-CL, 4.50%	80.6	80.8	80.6	1.25	3
PFS, 2.25%-CL, 6.75%	79.7	81.3	80.4	1.50	4
CL, 9.00%	84.3	83.1	83.8	0.89	3
PFS, 0.00%-CL, 0.00%	-	-	-	-	-
CL, 2.25%	62.9	47.4	55.2	5.56	20
CL, 4.50%	70.6	75.8	73.2	1.55	4
CL, 6.75%	80.0	78.6	79.2	4.16	11

1/ Standard error of the mean for gain in weight for the group of male and female rats.
2/ Coefficient of variation in % for the group of male and female rats.

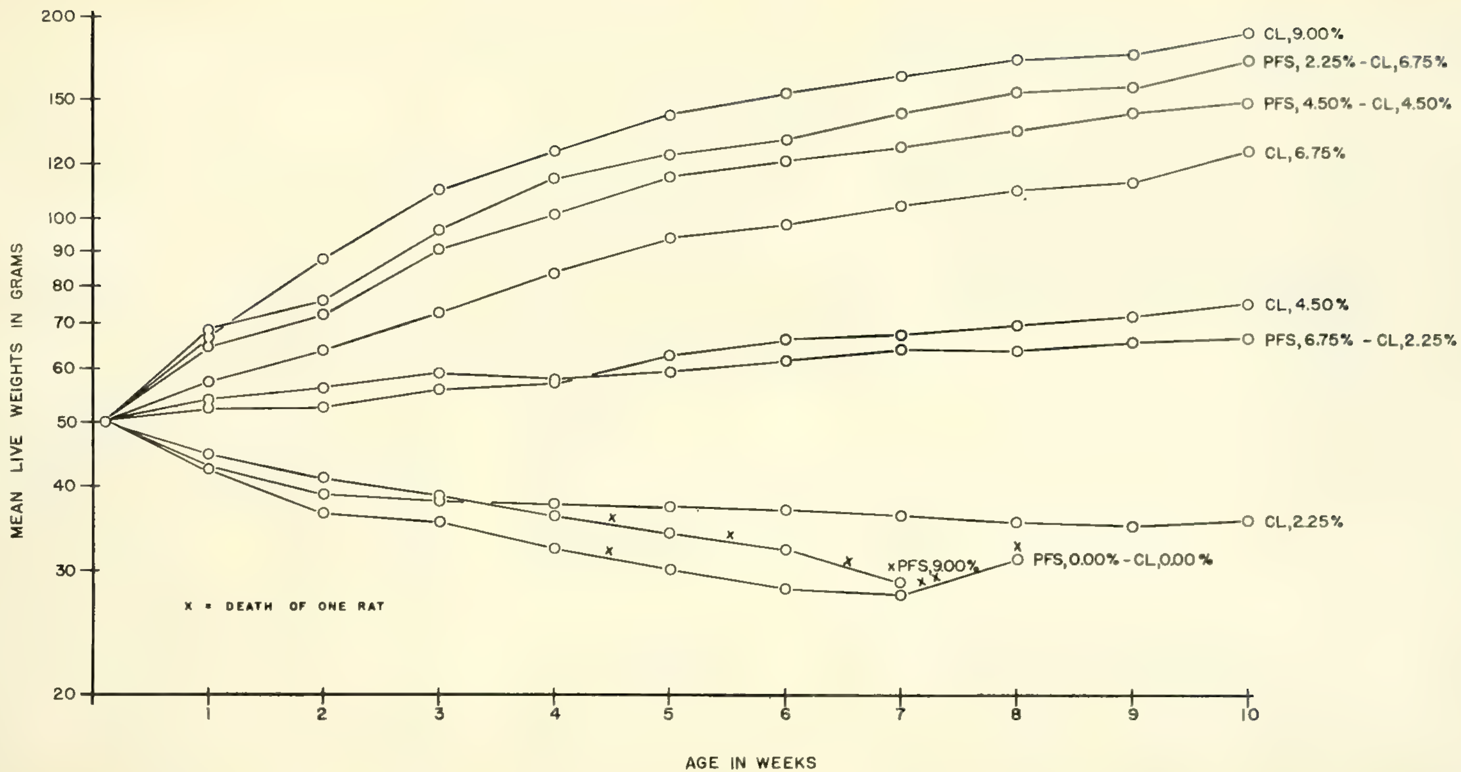

FIGURE 1

MEAN WEEKLY WEIGHTS OF GROUPS OF RATS FED DIETS
TO COMPARE POLLACK FISH SCALES AND CASEIN-LACTALBUMIN PROTEIN

BACKGROUND INFORMATION FOR VOLUNTARY GRADE STANDARDS ON NATURAL SPONGES

SPECIAL SCIENTIFIC REPORT–FISHERIES No. 273

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

EXPLANATORY NOTE

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United States Department of the Interior, Fred A. Seaton, Secretary
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BACKGROUND INFORMATION FOR VOLUNTARY GRADE STANDARDS ON NATURAL SPONGES

By Robert B. Bennett

For the Bureau of Commercial Fisheries
United States Fish and Wildlife Service

Contract No. 14-19-008-2378
University of Florida Project No. 5527

Department of Chemical Engineering
Engineering and Industrial Experiment Station
University of Florida
Gainesville, Florida

Special Scientific Report--Fisheries No. 273

Washington 25, D. C.

May 1958

The Library of Congress has cataloged this publication as follows:

Bennett, Robert Broadhurst, 1909–
Background information for voluntary grade standards on natural sponges. Washington, U. S. Dept. of the Interior, Fish and Wildlife Service, 1958.

60 p. illus. 27 cm. (U. S. Fish and Wildlife Service. Special scientific report : fisheries, no. 273)

Includes bibliography.

1. Sponges. I. Title. (Series)

SH11.A335 no. 273 639.7 59–60428

Library of Congress

The Fish and Wildlife Service series, Special Scientific Report--Fisheries, is cataloged as follows:

U. S. *Fish and Wildlife Service.*
Special scientific report: fisheries. no. 1–
[Washington] 1949–

no. illus., maps, diagrs. 27 cm.

Supersedes in part the Service's Special scientific report.

1. Fisheries—Research.

SH11.A335 639.2072 59–60217

Library of Congress [2]

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INTRODUCTION

According to Contract No. 14-19-008-2378, the work to be performed by the University of Florida Engineering and Industrial Experiment Station for the U. S. Bureau of Commercial Fisheries was the delivery of background information for a grade standard on natural sponges. In general, the objectives were:

1. To assemble information from which a voluntary Federal standard of grade and condition of sponges could be developed by the Bureau of Commercial Fisheries when the need for it had been demonstrated.

2. To prepare a report on current industrial practices in the classification of sponges. Sensory tests were to be supplemented by developed quantitative tests wherever possible.

3. To recommend a sound system of grading based on the above information, giving ranges and evaluation weights.

These objectives now have been achieved, and the results have been given in a report on file at the U. S. Bureau of Commercial Fisheries and at the University of Florida. Since that report is somewhat voluminous, owing to the fact that it contains most of the original data that were taken, it has been substantially abridged. The present report is the result of that abridgment.

References

A selected list of references is given at the end of this report. The system of grading proposed here differs markedly from most of those discussed in these references. Faults that require demerits in sponges are more numerous than are those in other products reported in the literature. Fortunately, these faults can be described and recognized readily--even to degree--by anyone skilled in the trade.

Worthy of special mention is the reference pertaining to fish sticks (United States Standards for Grades of Frozen Fried Fish Sticks), since the present work resembles in many respects that on the grade standards for fish sticks more closely than it does that on any other standards.

What Sponge Users Want

For background information, a census was taken of a cross section of customers in St. Petersburg, Florida as to what they wanted when they bought a sponge. The census indicated (1) that the user of sponges is interested in several properties present in natural sponges but not present in synthetic ones and (2) that wearability and ability to hold and release water are of prime importance.

Neither of these properties, unfortunately, is covered directly in the usual grading of sponges, but the graders are aware of their significance and include many tests that reveal differences influencing the rate of wear and the action of water in the sponge. The quantitative tests given in the present report appeared to members of the Sponge Exchange of Tarpon Springs, Florida, to have possibilities of satisfactorily measuring these two properties.

A more detailed discussion of the census that was taken on the use of sponges is given in a later section in the present report.

DESCRIPTION OF IMPORTANT SPONGES

The only commercially important sponges in this part of the world belong to the Keratosa family (De Laubenfels 1953, and Stuart). Radiating from the base of these sponges, is an interlaced fiber structure easily seen through a strong lens after the sponge has been cleaned thoroughly. The fibers are the spongin skeletons of the many small one-celled animals that make up the sponge. These cells are capable of individual existence for some time and of changing in form to assume one of the many duties of a colony of sponge cells, such as taking in food or throwing off refuse through separate channels set up for these purposes.

Most people are familiar with the similar cooperation observed in a colony of ants or in a hive of bees. The nearest analogy, but one less familiar, is the colony that forms a coral structure. Here the skeleton is of hard inflexible mineral matter. Even in sponges, one encounters some with skeletons containing varying amounts of minerals similar to sand or limestone. The skeleton of most sponges, however, is enclosed in a jellylike material that the cells have secreted and in which they can move. A mineral skeleton also may have been formed by the cells, starting usually with sharp, pointed spikes or spicules of mineral matter, which vary widely in shape, size and amount. The spongin or horn-like animal skeleton, all-important in the commercial Keratosa sponges, rarely is accompanied by these mineral spicules. A few other commonly occurring sponges such as the Loggerhead (not in the Keratosa group) probably would have been developed commercially, however, if their spicules were not so hard on the hands during the cleaning of the sponge.

The commercially valuable sponges have almost no spicules to injure the hands, and are given the description "Keratosa, 1-CC" by De Laubenfels, followed by: "The fibers are solid and opaque. The dried sponge is still spongy in consistency." (Either of these usually is adequate for identification.) "It neither emits a strongly colored exudate, nor a strong, unpleasant odor" when alive.

The "sheepswool" (or wool) type of Keratosa includes Rock Island, Inshore, Cuban, Florida Key, and Mediterranean sponges, although for grading purposes, these have to be described separately. This group has the scientific name of Hippiospongia lachne. When picked, the sponges in the group are drab to black and have a tough, smooth skin and many connected channels inside. The cleaned wool sponge, if examined with a strong lens, shows the parallel fibers present in all the commercial sponges but shows the cross fibers as being smaller, more abundant, and attached at angles approaching the parallel fibers. The colors cover the same range as do those of tanned leather, although occasionally, gray or rusty red variation occur, with the color being more concentrated in the base of the sponge and practically never working through to the surface. Such a red color is considered to be a fault. A very pale sponge may indicate artificial bleaching, whereas a very dark sponge usually indicates poor removal of gurry. Such uncleanliness is detected easily by an unusual stiffness when the sponge is dry and by a strong odor and milky wash water when the sponge is wet.

Inshore and Rock Island

Inshore-type sheepswool sponges (figure 1) are considered by scientists to be merely environmentally conditioned variations of the Rock Island sponge (figure 2). Originally, the tradesmen thought that the name was appropriate as indicating a relatively sharp division in the depth of collection; but many are convinced, by overlapping examples from both types, that the Inshore type is the result of factors of growth other than depth of water. Nevertheless, reclassification by the trade would be difficult to effect, so the present report did not eliminate samples of Inshore sponges when submitted for Rock Island tests. The tests on Inshores, however, were made after a few obvious Rock Island samples had been removed from the lots tested.

The actual division used by the trade at present is based almost entirely on the fact that Rock Island sponges are collected primarily by diving boats and that Inshore sponges are collected primarily by non-diving or hooker boats, which are smaller and collect closer to land with the aid of hooks on long poles.

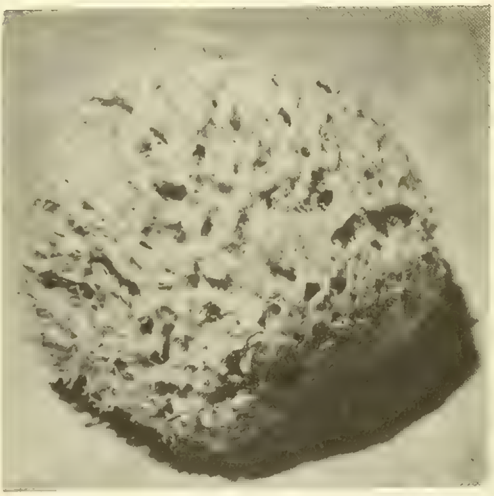


Figure 1.—Inshore Sheepswool

The Inshore type of sponge differs from the Rock Island type with intermediate degrees being quite common, by having more large internal holes and therefore a softer feel; and especially by having, on the surface, fine tufts or feathers, which often are curled. This feathery

Figure 2.—Rock Island Sheepswool

or hairy structure is more common close to the oscules or openings of the main channels. The Inshore sponges usually are better cleaned of gurry, but they have a greater proportion of other faults such as tears, sand, and minimum surface-bridging structure. An Inshore sponge present in a shipment of Rock Island sponges rarely is given a number-one grade.

These two types of sponges differ from the Bengasi (also spelled Benghazi) Mediterranean and Deepwater Mediterranean sponges in that they (1) seldom are flat, (2) have fewer holes and therefore more outside webbing or bridging structure, (3) are darker in color, (4) are more springy, and (5) regain their shape more readily when wet. As is true of hand tests with all commercial sponges, such testing should be performed on freshly soaked and squeezed samples.

Bengasi Mediterranean and Deepwater Mediterranean

Mediterranean sponges are included because they are sold in large amounts through Tarpon Springs. They differ from the Rock Island and Inshore types by having practically no surface tufting, and they appear to have some tufting clipped so that the webbing present is directly on the surface. When the dry sponge is rubbed on the hand, this surface webbing gives a feeling similar to that produced by a rubber balloon. A skilled inspector, by observing the flatter, paler, yellower, and more perforated appearance, can detect the Mediterranean sponge at sight, even when it is dry. In general, the Mediterranean sponges are more rounded and are cleaner from gurry than are the American sponges. The color is a paler yellow than is that of the Florida Yellow sponge, which has an orange tinge and is red-brown inside, and the holes are more scattered and numerous. The Deepwater sponge, when wet and squeezed well, is the softest of these sponges, but both of the Mediterranean sponges are slower to regain their wet shape. This relatively slow creeping back to shape can be seen by suddenly releasing the wet, squeezed sponge.

The Deepwater type of Mediterranean sponge is the most difficult to classify as being distinctly different from the Bengasi sponge (figure 3). The Deepwater sponge resembles the Inshore sponge by being softer and more porous than is its counterpart. Perhaps careful clipping of the Mediterranean sponges has removed tufts similar to those present in the Inshore sponges--tufts that would make them easier to identify. The greater softness of the Deepwater sponge is not detected easily except when the sponge is wet. It is puzzling that the Deepwater Mediterranean sponge appears to be the softer of the pair, since the American Inshore sponge, which usually is found in relatively shallow water, is softer than is its deepwater twin, the Rock Island sponge.

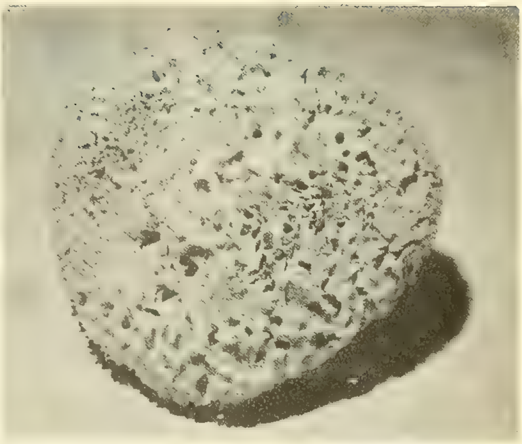


Figure 3.--Mediterranean Bengasi

Florida Key Wool or Sheepswool

The Florida Key Wool or Sheepswool sponge (figure 4) is similar to many sponges marketed as Inshore sponges. It resembles a cross between the Inshore sponge and the Mediterranean sponge in that it usually has the feathery outside surface of the Inshore sponge, but it contains relatively more holes between 1/8 and 1/4 inch in diameter and, in general, is flatter on top. Relatively more of the Florida Key Wool sponges possess red bottoms and weak inside structure. This description differs from that given by Stuart (Series No. 82), who seems to have described a poorer type that may have made a slow recovery from the Blight of 1939 to 1946.

Cuban Sea Wool

The Cuban Sea Wool sponge (figure 5) is another type of Sheepswool sponge, judging by the samples received. Except for a tendency to be taller than it is broad, it most nearly resembles the Mediterranean types in that it contains many holes, has very little surface webbing or tufts, and is softer than is the Rock Island type.

No differences in the fibrous structures of any of the above wool sponges could be detected with a good magnifying glass. An examination

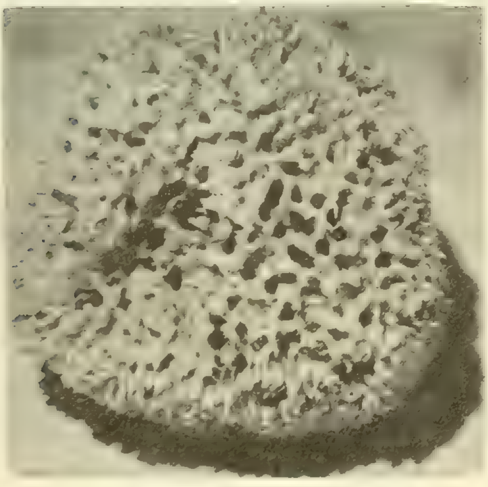


Figure 4.--Florida Key Wool

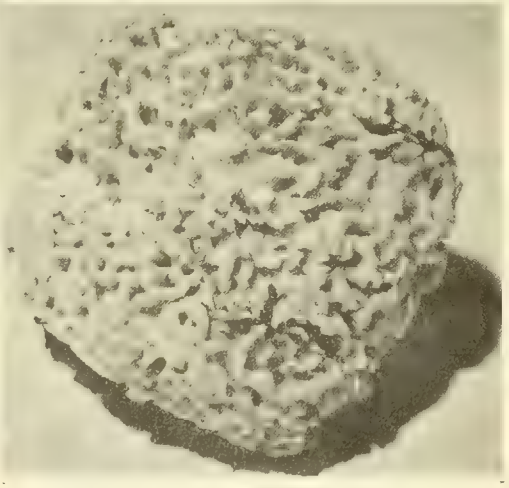


Figure 5.--Cuban Sea Wool

for spicule types and similar factors as described by De Laubenfels (1953) might reveal important differences under high magnification, but such an examination is not practical for commercial identification. The differences in wool-type sponges, easily detected by one skilled in grading, are difficult to describe in terms other than the ones used above.

Florida Yellow

The Florida Yellow sponge (figure 6) possesses a reddish-yellow to reddish-brown color that ranges between the yellow of the Mediterranean sponges and the leather-to-gray color of the Rock Island sponge. The darker red-brown inside is quite characteristic and uniform. The scientific name is Spongia zimocca or barbara, and it belongs to the Keratosa order. Alive, it is drab to black, with many small holes. These holes may protrude as volcanoes, which are not large in the cleaned sponge. The Florida Yellow sponges are much stiffer both wet and dry, than are other sponges except the Grass sponges. The Florida Yellow sponge is highly elastic and regains its shape instantly. It has high water-holding power, contrary to popular opinion, but it does not release water easily, owing to its stiffness. A Yellow sponge can be distinguished easily from a Grass sponge by tipping the wet and drained sponge. Much extra water will drain from a Grass sponge because of its preponderance of large channels running in one direction. The Florida Yellow sponge, under a lens, resembles a Grass sponge in that its parallel fibers are larger than are the cross fibers; but the Florida Yellow sponge has a greater proportion of cross fibers, and these cross fibers are not so nearly perpendicular to the vertical fibers as they are in the Grass sponges.

Figure 6.—Florida Yellow

Any sponge that is relatively stiff, both wet and dry, has a red-brown interior, and splits fairly easily from the top down when pulled apart with the fingers is probably a Florida Yellow sponge. No sponge described by Stuart (Series No. 82) appears to be this sponge.

Anclote Grass and Hudson Grass

The Anclote Grass sponge (Spongia graminea) (figure 7) is sold almost always as "cuts," since it grows in the shape of a vase, which is not so much in demand as is the spherical shape. Alive, it is drab to black, but the cleaned sponge is pale yellow to dark brown, depending on the treatment. These cut slabs, resembling a small-holed honeycomb, have many large holes and ridges running the length of the sponge. These, and their extreme stiffness when dry, make them easily identifiable. Many samples, however, will vary up to the Hudson Grass sponge (figure 8) in character.

Figure 7.—Anclote Grass

The typical Anclote sponge has very little outside loose fiber except on the top edges; whereas the typical Hudson Grass sponge (1) is broader, more hairy all over, and less ridged and (2) has smaller-pored interior resembling the Florida Yellow sponge. Both grass sponges, when wet and drained flat but unsqueezed, pour out much water when they are tipped to the vertical position. Grass sponges, under the lens, show more open structure and fewer cross fibers, and these cross fibers are attached more nearly perpendicular to the large parallel main fibers.

The Hudson Grass sponge, which is relatively new on the market, appears to be similar both to the Bahama Yellow sponge and to the Bahama Velvet sponge described by Stuart. The Hudson sponge was described above as being different from the Anclote Grass sponge. It might be confused, however, with the Florida Yellow—as well as with the Anclote—owing to the red-brown interior, but no other sponge on the market bears the fairly uniform hairy surface. The hairs tend to concentrate toward the top edge of the sponge, as its variations approach those of the Anclote Grass sponge. The Hudson Grass sponge is as stiff as is a Florida Yellow sponge when wet, and it does not compress as readily on its side as does the Anclote Grass sponge, owing to the reduced size of the main tubes. In other water tests, as will be brought out later in the report, it parallels the Anclote Grass sponge.

The Blight seems to have changed the availability of sponges. Almost no Wire, Velvet, Reef, or Glove sponges now can be found. They, however, never were of great industrial importance.

Interestingly, all of the sponges described in this report are composed of absorbent cages made of fibers, whereas the synthetic sponges examined were composed of spherical cells that had some common walls and opened into each other through small holes. These differences should have a definite effect on some tests and uses.

Grading by the demerit system proposed here differs somewhat from the system of grading presently used by the trade. The following gives a general description of each system.

Present System of Grading

The techniques now used in the trade for the inspection of sponges are entirely qualitative and sensory. That is, the grader does not add or subtract numerical values for good or bad qualities of a particular sponge. The sensory tests include the use of sight, feeling and smell.

Figure 8.—Hudson Grass

The sponges are sorted into the types described in the preceding section, dropped sidewise through holes graduated in steps of one-half inch to determine the maximum diameters, sorted into "forms" and "cuts," and then inspected to determine into which one of four grades they should be classified--No. 1, 2, 3, or 4. A grade No. 5 has been used, and the number grades have been subdivided into A's, B's and Specials, but these additional subdivisions are reported to be unnecessary complications designed to produce a higher price than that which the sponges ordinarily would yield.

"Forms" are those sponges that are most perfect, especially in shape, with a spherical shape being the one most desired.

"Cuts" literally may have been cut from larger sponges, or they may be sponges that have been distorted in other ways by the clipping out of a diseased or torn spot or by the irregular growth due to the presence of another sponge or of a rock, shell, seaweed or crab. A crab hole is a dished spot or actual hole caused by some form of marine life. Grass sponges usually are sold as "cuts" because the demand is low for the vase shape that is the natural pattern of growth of the Grass sponges.

"Rollers" are seen occasionally. If a sponge has grown without being attached permanently to a rock or similar support, it becomes a roller with the ocean current. This movement across the bottom of the ocean causes it to accumulate dirt and to acquire a tough outer skin. Accordingly, it is classified into a much lower grade.

Size, as it affects the price (figure 9) of the sponge, does not follow the expected pattern. Roughly, the price is directly proportional to the diameter rather than to the cube of the diameter as one would expect if the price were related to the volume of the sponge. (Volume equals pi divided by 6 and multiplied by the cube of the diameter or $V = \frac{\pi D^3}{6}$.) Except for display purposes, most sponges more than 8 inches in diameter sell slowly and, accordingly, are cut into sizes that are easier to hold. The work of cutting and trimming and the loss of material incurred just about offset the value of the extra volume in a larger sponge.

The curvature and the slope of the lines in figure 9 will be affected by changes in the supply and demand for different sizes at different times.

Until quite recently, many sponges were sold on the basis of weight. Sale by size now is recommended by the members of the Sponge Exchange, and measurement of the perimeter of the sponge is preferred over measurement of the maximum diameter used by many, as well as over the three-diameter method suggested here. Details on the above points will be discussed later in this report.

Demerit System of Grading

The details of inspection by the demerit system have been placed under proper headings in the following section on Discussion of Faults but an overall picture of the method of grading is described at this point.

Except for work in the Sponge Exchange or in packing houses, most of the inspections take place after a shipped bale or box of sponges has been opened. These sponges are found to be highly compressed and should be sampled according to section F of Federal Specification C-S-631b for "Sponges; Natural," which is in Part 5 of Section IV of the Federal Standard Stock Catalog.

The sponges should be wet and squeezed thoroughly before being inspected. The perimeters should be measured according to the Federal specifications or, if the agreement requires, should be checked for size by a "go - no go" test by means of standard boards with circular holes decreasing in diameter in steps of one-half inch. The three diameter test described later under Miscellaneous Studies may merit consideration, however, since it (1) gives more data than do the "go - no go" boards, (2) is quicker than are perimeter tests, (3) gives one number that approximates the "go - no go" tests, and (4) causes no arguments as to whether the perimeter tape was poorly placed, was too loose, or was too tight.

It might be worthwhile also to specify a minimum rate of sampling for lots of different size in the manner specified on page 5 and

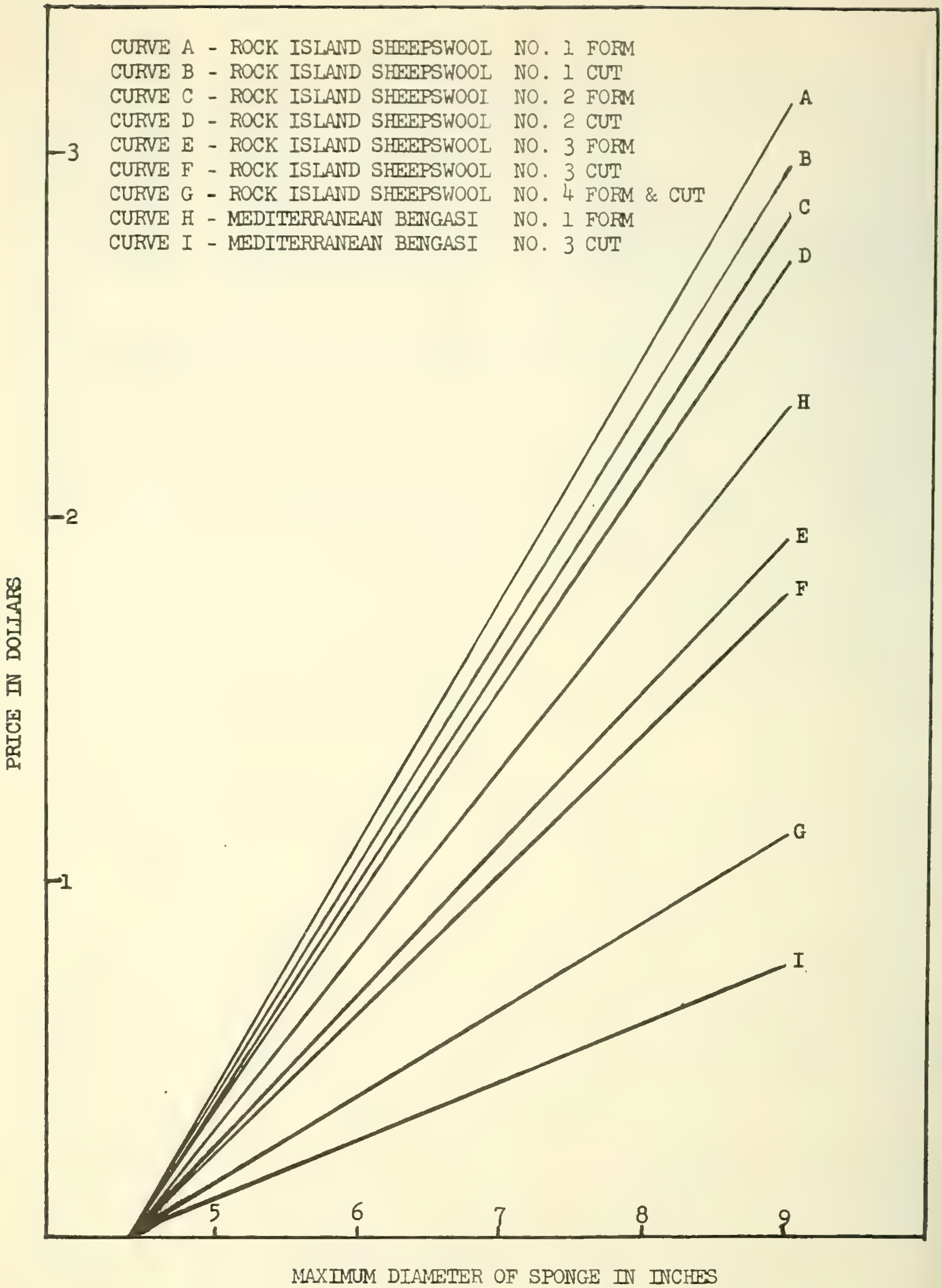


Figure 9.--Relationship in the fall of 1955 between the price of natural sponges and their size.

section 52.38 in the reference on processed fruits and vegetables. Other suggestions for changes in Federal Specifications are discussed later.

Grading for demerits usually proceeds as follows for the individual, thoroughly wet and squeezed sponge:

1. Check for trueness to type according to the "Description of Important Species," given earlier. Any lot containing sponges not true to type should be rejected as being impossible to grade. Such lots should not be encountered, however, since an experienced seller would not make this mistake.

2. Check the sample for size according to a mutually accepted standard method. It is suggested that not more than one-sixth of the samples fails to meet the size indicated—to borrow the phrasing common in Agriculture Standards. An adjustment in price could be made if this requirement as to size is not met.

3. Look for faults:

   a. Smell the sponge for strong odor.

   b. Squeeze out a few drops of water to detect gurry.

   c. With both thumbs first placed on top of the sponge, run them down the sides at several spots and look for holes and other faults.

   d. Inspect the bottom for dirt, holes, and looseness.

   e. Use the thumb and forefinger for squeezing to detect interior dirt, such as shells and rocks.

   f. Squeeze the whole sponge in one or two hands to detect elasticity, stiffness, poor recovery of shape, or weak inside structure.

   g. Inspect surface structure and shape closely.

   h. Test for brittleness and tendency to split.

   i. Run any special tests for a particular type or use.

4. Assign demerits to the sponge according to the agreed standard system of demerits.

5. Determine the grade of the sponges in the lot by considering the average number of demerits that were assigned to the sponges in the given lot.

DISCUSSION OF FAULTS

As was indicated in the preceding section, the individual sponge is given demerits for each fault that is found by inspection. The maximum number of demerits given depends on the seriousness of the fault. This maximum number ranges from 50 to 300.

The faults are divided into two groups: major and minor. Major faults are those requiring a maximum of 200 to 300 demerits. Minor faults are those requiring a maximum of 50 to 150 demerits. Both the major and minor faults, in turn, are divided into two sub-groups: workmanship and character. Faults included under workmanship are those controllable by the seller. Those included under character are controllable only by selection and grading.

A list of the faults and the maximum number of demerits suggested for each are shown in table 1. A typical example indicating how many demerits would be assigned in actual practice to one lot of sponges of a particular type and grade is shown in table 2. The following gives a discussion of each fault.

Major Faults

A. Bleached.--To determine the color of a bleached sponge, one could use an accepted publication of color standards for reference, but customers are not interested particularly in the attractiveness added by bleaching. Evidently, sellers are aware of this fact and also of the fact that all known methods of bleaching are reported to weaken the sponge, since very few domestic sponges received were definitely bleached. The few that were given demerits for being bleached could have been affected by variations in growth or by exposure to sun, which seems to have been the case for the Mediterranean sponges that were inspected. Bleaching may be partially the cause of certain of the accompanying poorer qualities in these sponges. At present, the only advice that can be given on grading this fault is to say that familiarity with the usual color will make possible the detection of any excessive amount of bleaching.

B. Unclean, gurry.--Uncleanliness is indicated by excessive stiffness in the dry sponge, which almost invariably is accompanied by a color that is darker than usual and by a clinging together of the finer outside fibers. The Rock Island sponges were found to be the least cleaned of gurry (residual dried oxidized flesh). Such sponges, when wet, often will evolve a fishy smell, feel sticky, give a milky discoloration to the first wash, and leave a smear on clean glass. On thorough washing, no sponge should lose more than 10 percent of its weight figured on the dry basis.

This test gives additional evidence that the sale of sponges should be made on the basis of size rather than of weight. Practically all sponges now are being offered for sale on a size basis,

Table 1.—List of faults and the maximum number of demerits given for each one

Faults	Maximum demerits given each fault
Major	Number
Workmanship	
A. Bleached	250
B. Unclean, gurry	200
C. Weight additives	200
D. Exterior sand, shell, coral, stone	200
E. Interior sand, shell, coral, stone	250
F. Odor	200
Character	
G. Tears	250
H. Holes, natural, too large or through	300
I. Holes, "crab," baring inside	250
J. Holes, "crab," webbed, or uneven bottom	200
K. Holes, natural, small, from disease	250
L. Structure weak inside	250
M. Lacking outside webbing over holes	200
N. Surface, roller type, no nap	300
O. Surface, inshore type feathery	300
P. Red bottom or body	200
Q. Feel: not springy	300
R. Strength: easily split	300
S. Brittle under pinch or pull	200
T. Low water absorption	300
U. Wet stiffness: poor cleanability	200
V. Wet drainage when tipped	300
Minor	
Workmanship	
A. Ragged clipping	50
B. Seaweed, etc., soft	50
C. Seaweed, etc., hard	100
Character	
D. Too flat	150
E. Too long	50
F. Too tall (e.g. vertical cuts)	100
G. Volcanoes	100
H. Side or top valleys or branches	150
I. No bottom webbing	100

Table 2.—Sheepswool sponges graded by demerits—No. 1 Forms

Faults	Maximum demerits given each fault	Demerits given to individual sponges[1]																	
		RIS 1F5	S 1F7	S 1F6	S 1F8	1F5	N 1F15	RIM 1F26	S 1F3	S 1F4	N 1F8	1F12	1F11	1F9	1F1	1F5	1F4	1F10	1F8
Major	Number	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
Workmanship																			
A. Bleached	250	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B. Unclean, gurry	200	20	20	5	20	—	—	20	—	—	—	—	—	—	—	—	—	—	—
C. Weight additives	200	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
D. Exterior sand, shell, coral, stone	200	—	—	5	—	—	—	—	20	—	10	—	—	10	—	—	—	—	—
E. Interior sand, shell, coral, stone	250	—	—	—	—	—	—	—	—	30	—	—	—	—	—	—	—	—	—
F. Odor	200	—	—	—	—	—	—	5	—	—	—	—	—	—	—	—	—	—	—
Character																			
G. Tears	250	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
H. Holes, natural, too large or through	300	10	20	—	—	—	10	—	10	30	30	10	—	20	30	—	20	—	—
I. Holes, "crab", baring inside	250	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
J. Holes, "crab", webbed, or uneven bottom	200	20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
K. Holes, natural, small, from disease	250	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
L. Structure weak inside	250	—	—	20	5	—	15	—	—	—	—	—	—	—	—	—	—	—	—
M. Lacking outside webbing over holes	200	5	20	10	—	20	—	5	30	20	—	—	20	20	—	10	20	10	20
N. Surface, roller type, no nap	300	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
O. Surface, inshore type, feathery	300	—	5	5	10	—	5	—	—	10	10	—	—	—	—	—	—	—	—
P. Red bottom or body	200	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Q. Feel: not springy	300	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R. Strength: easily split	300	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S. Brittle under pinch or pull	200	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
T. Low water absorption	300	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
U. Wet stiffness: poor cleanability	200	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Minor																			
Workmanship																			
A. Ragged clipping	50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B. Seaweed, etc., soft	50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
C. seaweed, etc., hard	100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Character																			
D. Too flat	150	—	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E. Too long	50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
F. Too tall (e.g. vertical cuts)	100	—	—	—	—	—	—	—	—	—	—	—	—	—	10	—	—	—	—
G. Volcanos	100	5	—	5	—	5	—	—	—	—	—	—	—	—	—	—	—	—	—
H. Side or top valleys or branches	150	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
I. No bottom webbing	100	—	—	—	—	—	—	—	—	—	—	10	—	—	—	10	20	—	—
Total demerits:		60	75	50	35	25	30	30	60	80	50	30	20	40	50	20	60	10	20
Average demerits:		49.5																	

[1] The designation RIS, S , S , and so on are used to identify each individual sponge.
1F5 1F7 1F6

although they still can be bought on a weight basis, as they have been for many years. In the past, the problem of gurry in sponges has been a serious one for the industry. A specification as to cleanliness therefore is recommended to prevent this problem from recurring.

C. Weight additives.—When sponges were sold on the basis of weight, gurry and dirt sometimes were left in the sponge intentionally. Weight additives also were worked into the sponge. A specification for uncleanliness will deter any tendency for the industry to slip back into these uneconomic practices, which work against its welfare under competitive conditions.

Although each seller of sponges who "loaded" them had his own formula, in every case known, the weight additive could be washed out with water. This fault therefore merely requires an extra 200 demerits to be added to Fault B if evidence of loading is found.

Weight additives fall into two classes: water soluble and water insoluble. The water-soluble type would be suspected if the sponge lost a lot of weight on being washed but did not develop a foul odor (due to gurry) when wet and kept in a closed container for 24 hours. The water-insoluble type, usually needing the first type to make it adhere to the sponge, would be fine sand, barytes, whiting, litharge, or similar insoluble material, which easily can be detected by an examination of the first wash water for insoluble fine powder. Sale on the basis of size rather than weight, however, gives no incentive to load a sponge or to leave in more than 10 percent of gurry.

D. Exterior sand, shell, coral, stone, etc.—Inspection of the bottom of the sponge usually will reveal most of the exterior dirt. Complete removal of dirt is difficult and time consuming without destroying some of the bottom webbing, which is one of the stronger parts of the sponge. Very little if any such dirt should be tolerated, however, in the present market, which is so keenly competitive. Synthetic sponges never contain dirt, and Mediterranean sponges are almost as clean. Obviously, very few uses of sponges will tolerate harsh particles. Even a small amount of dirt therefore justifies large demerits if the inspector finds that the dirt is easy to remove without injuring the sponge.

Several people in the trade have recommended that sponges be clipped from their roots. If the root is left to grow a new sponge, production is increased, and very little bottom dirt is collected; but the new sponge tends to grow in a flatter shape, which results in few forms, and the strong bottom webbing is lost. The advantages of clipping the sponges from their roots appear to outweigh the disadvantages, however, if one realizes that the value of the spherical form is questionable in view of the competition with the synthetic sponge.

E. Interior sand, shell, coral, stone, etc.—When dirt such as sand and shell would be difficult to remove without injuring the sponge, the sponge cleaner is confronted with a difficult decision. He may have to make cuts from a good form, downgrade the sponge because of the cut, or run the risk of having the sponge downgraded or rejected by the buyer.

Large particles can be detected by pinching the whole wet sponge at different spots, whereas small particles—usually sand—can be detected by close visual inspection through the channels. Some sponges, especially those of the Grass and the Inshore types, tend to incorporate small particles of sand and shell during their growth. Mediterranean sponges, likewise, sometimes appear to grow around particles or stone. These small objects are almost impossible to remove and, accordingly, might be considered to be a character fault instead of one of workmanship. In either case, however, the demerits for these faults should be major.

F. Odor.—Odor invariably will accompany poor removal of gurry if the wet sponge is kept in a closed container for 24 hours. At that time, the sometimes mild fishy odor develops into a strong one resembling ammonia. It obviously lowers the value of the sponge to the consumer. Customarily, however, demerits are assigned only on the basis of the odor of the freshly wet sponge. Such practice was followed by the writer in his studies of grading. It should be kept in mind, however, that a gurried sponge that has been dried rapidly in the sun may develop little odor when it is freshly wetted.

G. Tears.—The first major fault of character in the list given earlier considers any definite separation of the main body—not the surface fibers--to be a tear, whether it be caused in collecting, in removing an embedded shell, or in too drastic cleaning--such as running the sponge through wringing rolls. Tears show up quite readily during the initial handling by the inspector. The wet sponge is held in both hands, with thumbs on top of the sponge, and the thumbs are allowed to slide, with pressure, down the sides of the sponge. Repeated on two to five diameters, this procedure will reveal the tears. This same riffling, with the roots up, will reveal the bottom imperfections, including dirt and crab holes. Serious tears rarely appear in the marketed sponges, since torn spots are removed before the sponges are sold.

H. Holes, natural, too large, or through.—The writer has graded the sponges according to the custom of giving large demerits if the channels run through to the bottoms so daylight can be seen through them. Actually, the thin bottom webbing that saved many other sponges from receiving such large demerits probably does not give much longer life to the sponge. Holes larger in diameter than 1/2-inch should be given demerits in proportion to the diameter of the holes and to the number of them. Such holes tend to form weak spots from which tears eventually will start during the useful life of the sponge. It is difficult to set up a numerical proportion between demerits and the number or size of holes, but each hole larger in diameter than 1/2-inch should be given 50 demerits, or more, depending on the size.

I. Holes, crab, baring inside.—Final users will agree with the writer's division of crab-hole grading to assign slightly more demerits to a hole that is unlined by protective tissue. Crab holes are made by many forms of life other than crabs. The result, however, is the same. The hole may appear anywhere—on the surface or in the interior. Surface grooves usually wear a protective coating or webbing similar to the usual bottom structure and, as such, are covered in Fault J, but sometimes an interior hole—usually starting close to the bottom and rarely penetrating the top—bares the inside structure and is not protected by webbing. Such defects should be given demerits as large as those for tears. They usually drop the rating of the sponge by one grade.

J. Holes, crab, webbed; or uneven bottom.—Since the effect is the same with uneven bottoms as with webbed holes, these faults have been combined, whether they be due to webbed crab holes, to another sponge growing closely nearby, or to a stone or shell on which the sponge was growing. The resultant distortion, if large enough, may cause a Form to be graded as a Cut.

K. Holes, natural, from disease.—The writer was alarmed to find a fair number of sponges that contained areas of sleazy or thin growth, since these might indicate the persistence of blights, even though they were being kept under control. Such a spot, or its trimmed place, would justify demerits somewhat more than would a lack of webbing over a corresponding area (see M).

L. Structure, weak insides.—Softness is another fault that is difficult to evaluate. A soft sponge, as tested by pinching or squeezing the whole wet sponge, may be attractive at first to the majority of customers, but this fault usually indicates that less material is present and that accordingly, a shorter life is to be expected. It should therefore receive demerits. On the other hand, the Grass sponge and the Florida Yellow sponge usually are too stiff for ready acceptance except for special uses. The greater proportion of water that can be removed from a Hudson Grass sponge than from an Anclote sponge (see Cleanability, under the quantitative tests) because of an apparently weaker inside structure, conceivably could be considered as being an advantage. For purposes of inspection, a squeeze of the sponge with the full hand will reveal any definitely weak inside structure. If demerits have been made for excessive holes, the number of additional demerits for weak structure has to be determined by closer visual inspection for loose fine structure.

M. Lacking outside webbing over holes.—Although the useful life of a sponge is much greater than is the time elapsed in wearing through the outside fiber and webbing that form the surface of the sponge, this webbing probably constitutes a resistant layer that reduces tearing during its existence. A reduction in the amount of this webbing therefore should receive demerits. The initial riffling by the inspector to uncover holes and tears will reveal the percentage of surface webbing. (Bottom webbing is covered under I in Major Faults.)

N. Surface, roller type; no nap.—Rollers rarely are encountered in the trade, owing either to the fact that they are considered practically worthless or to the possibility that the conditions that caused them have improved. One reported source is a sponge that is lost by the collector before it has been exposed to air long enough to be killed. The dropped sponge continues to live, but it rolls with the currents on the floor of the ocean and acquires the characteristic lack of surface fibers and equally characteristic bottom structure over the entire sponge. The presence of this bottom structure is a minor item, as it can be argued that such a sponge should bring a premium, owing to its greater resistance to wear. It should be given a fault rating, however, to prevent the uninformed buyer from being sold an item that is reputedly off grade.

O. Surface, inshore type, feathery.—Feathery structure is another case of a property that could be attractive to some buyers. The Hudson Grass sponge sometimes brings a higher price than does an Anclote sponge, owing to a feathery or hairy structure. This structure makes a softer sponge of a type of sponge that usually is too stiff. An arbitrary plus 50 points therefore are given to a typical Hudson Grass sponge for this property. (Note: In the system of grading recommended in this report, to give plus 50 points is actually to subtract 50 demerits.) On the other hand, the Inshore Sheepswool type is most easily distinguished from the Rock Island type by means of this feathery structure, which often is accompanied by other less desirable properties. Points can be taken off in proportion to the percentage of surface covered by such feathery structure and to the length of such fibers, which may reach 1/2 inch. The feathers may wear away rapidly and therefore deserve demerits aside from other accompanying undesirable properties.

P. Red bottom or body.—If wear tests had proved to be more significant, it was planned to check one possible reason for the downgrading of sponges that appear to have been discolored by a deposition of iron oxides. No consistent trend to poor properties, however, appeared to accompany such discoloration. Rock Island sponges rarely are so colored. The discoloration therefore, at one time, may have served as a quick check as to type. In the author's examinations, Florida Yellow sponges were quite consistent in the degree of such redness and accordingly received a uniform demerit of 100 points. Using this standard color and demerit as a guide, the inspector can estimate the degree of discoloration, with 200 demerits as a maximum to be applied. As in A, the use of a scientific color designation would depend on a balance of the cost of the research needed to develop the designation versus the benefit to be derived.

Q. Feel, not springy.—According to the apparent judgment of the trade rather than being based on the accompanying quantitative tests for elasticity, this fault was set up to cover apparent hardness or stiffness that prevents an inspector from compressing the sponge to any large extent. By strict definition, the fault should be labeled "low compressibility," but the word "springy" conveys more to the average person. To reduce the number of faults, the author used this term to cover low visual snap back due to hardness or stiffness and also to cover the other occasional lack of snap back or springiness encountered in relatively soft sponges that appear to be soggy. This deadness is encountered occasionally in sponges that have been dried at too high a temperature or that have been squeezed too drastically in the cleaning step. The Florida Yellow sponges have received demerits due to their uniformly hard character, and an occasional sponge of the other types has received some demerits for being soggy.

R. Strength: easily split:—If the riffling step is modified by first pressing the sponge tightly before the hands are rotated, a splitting force is exerted that will tear open some sponges. The Grass and Florida Yellow sponges often show this fault, but more often it is accompanied by a lack of surface webbing in any sponge. A lack of bottom webbing allows the sponge to be split easily from the bottom. Several noncommercial sponges may owe their lack of development to this fault. Judgement as to the proper relative rating can be obtained only through experience.

S. Brittle under pinch and pull.—Grass, Florida Yellow, and highly bleached sponges often fail under the test for brittleness, which involves pinching a small tuft between fingernails of thumb and forefinger followed by pulling and twisting to break off a portion. Again, experience cannot be put into numerical description. Such brittleness would be expected to be accompanied by poor wearing qualities.

T. Low water absorption.—If no quantitative tests are used, the rating given this fault of low absorption of water indicates the inspector's opinion as to the relative value of a particular type of sponge, since the property of water absorption is one of the most important to the ultimate user of the sponge. Briefly, it consists of an estimate of the relative weight of water that can be picked up by the sponge on the first wetting. The writer suggests that this be the first subjective test to be replaced by a quantitative one.

U. Wet stiffness: poor cleanability.—In looking for properties that would justify the low prices brought by the Grass and the Florida Yellow sponges, the writer decided that wet stiffness was one of the very important properties. Quantitative tests reported later in this report verified this conclusion. The inspector judges this property by the relative amount of water that can be squeezed out of the sponge. The amount of water absorbed and the amount squeezed out both are judged by gentle swinging of the sponge up and down to feel the weight. The term "wet stiffness" is not used in the trade, and the use of it therefore may not be desirable; but it does describe accurately the property that causes poor cleanability, or difficulty in squeezing out the water that has been absorbed. A porous brick may absorb as much water for its size as a sponge does, but it would be a worthless substitute, owing to the fact that water cannot be replaced by squeezing and rewetting.

V. Wet drainage when tipped.—An easy test of identity for Grass sponges can be run by thoroughly soaking the sponge, laying it gently to drain on its flattest side without tipping, then tipping it by lifting it by the top tufts. From a third to a half of the water will pour out of the Anclote and Hudson Grass sponges in less than a minute. In general, Anclote sponges will drain faster than will Hudson sponges. For most uses, this property would be a disadvantage, so demerits are given for it. In sponges used for cleaning with other solvents, however, this property could be an advantage. It would enable such a sponge to be rinsed out readily without hand squeezing, for example, which would be a convenient property when some solvent such as gasoline is used to clean greasy motors. A quick quantitative test could be set up to rate sponges according to this property, but it was thought to be of minor importance at this time. A qualitative hand test, however, is as easily evaluated as are the tests for absorption and cleanability.

Minor Faults

A. Ragged clipping.—Only occasionally does the inspector encounter sharp corners left in sponges by poor clipping. Nothing but the appearance is improved by smoother contours, however, so very few demerits are justified for this defect. It is notable that Mediterranean sponges are more carefully contoured than are the domestic sponges. Failure to remove a tear by not making cuts from a form, may justify all 50 demerits.

B. Seaweed, etc., soft.—Since it takes time to remove the last traces of soft seaweed often found inbedded in the sponge and since complete removal may be difficult without ruining the sponge, very few demerits are justified for this defect. Furthermore, the soft material soon washes out during use and causes no harm to the surfaces being washed.

C. Seaweed, etc., hard.—A more serious inclusion of woody growths that might scratch surfaces deserves a greater number of demerits. More than 100 points would be justified except that almost invariably, such particles are noticed the first time the sponge is squeezed and are easily pulled out.

D. Too flat.—Flatness and associated faults are considered to be important only from the standpoint of appearance unless the irregularities in shape are so extreme as to cause breakage of the sponge in use. Since these shape faults are the most important in classifying the sponge as a Cut rather than as a more valuable Form (other than an obvious product of cutting), they may have been relatively more important in the past trade than what the writer has allowed in the present demerit system, but the data accumulated in this study do not justify larger demerits. As a rough guide to the inspector, any sponge less than half as high as its radius in the horizontal plane would receive close to 150 demerits.

E. Too long.—As distinguished from Fault D, a sponge can be narrow—or too long—as well as being too flat. If one horizontal diameter is more than twice the other, a full 50 points should be deducted.

F. Too tall.—Cuts made in the plane vertical to the base or root of the sponge—this being the usual method of cutting—often cause a sponge to be tall enough to be unattractive. Grass sponges are almost invariably cut this way, owing to the fact that the original form is vase-shaped and awkward to use. Some Cuban Wool sponges appear to grow quite tall. A full 100 points should be taken off for heights more than twice the length of the longest horizontal diameter.

G. Volcanoes.—Almost all types of sponges show a variation occasionally toward projecting tissue around the channels or oscules. The trade appears to downgrade such sponges fairly severely, and therefore it is surprising that the projections are not trimmed. Volcanoes usually are accompanied by a weak structure, but they receive demerits here merely because of poor appearance. Volcanoes more than 1/2 inch high would receive a full 100 demerits, since they rarely occur with single holes.

H. Side or top valleys or branches.—Except in the Grass and the Florida Yellow sponges, side or top valleys or branches usually are trimmed away. Projections greater than an inch should receive a full 150 demerits if the valleys are quite sharp, since breakage occurs easily at these lines.

I. No bottom webbing.—Fortunately for eventual acceptance of sponges cut to leave the bottoms to grow again, the fault of no bottom webbing does not receive much downgrading in the trade. Lack of bottom webbing, however, can cause a quick breakup of the sponge in use. If it were not for advocating the leaving of the root to grow again, the writer would recommend a more drastic penalty than 100 demerits for a complete lack of bottom webbing.

AVERAGE NUMBER OF DEMERITS CHARACTERISTIC OF EACH TYPE AND GRADE OF SPONGE

When the system of demerit grading described in the preceding section is applied to sponges, the average number of demerits assigned to a lot varies both according to the type of sponge and to the grade of sponge. With Rock Island Sheepswool sponges, for example, No. 1 Forms will average 50 demerits and No. 3 Forms will average 425 demerits. On the other hand, with Mediterranean Deepwater sponges, No. 1 Forms will average 350 demerits and No. 3 Forms will average 630 demerits. Thus, the average number of demerits varies according to both the type and the grade of sponge under consideration.

In practice, we find that the number of demerits assigned to an individual sponge varies widely from the average for its type and purported grade. The question naturally arises as to what is a reasonable variation. It is suggested that a good basis of judgment would be to consider the magnitude of the variation in relationship to the midpoint between the average number of demerits characteristic of the purported grade and the average number characteristic of the next grade.

The fact that the number of demerits assigned to a particular sponge deviates widely from the average for its grade shows the need for careful sampling in the grading of sponges.

In the event that the demerits assigned to individual sponges in a lot are found to deviate too widely from the average for the purported grade of the lot, there are two possible solutions to the problem: (1) regrade the individual sponges or (2) assign a different grade to the lot as a whole. In either case, the basis for reassignment of grade could be the midpoint between the average number of demerits characteristic of the purported grade and the average number characteristic of the next grade.

It thus becomes important, in the demerit system of grading, accurately to determine the average number of demerits characteristic for each type and grade of sponge and the midpoints between these characteristic numbers.

Accordingly, the various types of sponges were graded by the demerit system in order that the characteristic number of demerits for each type and grade could be determined. The results are reported in the following subsections.

Rock Island

Table 3 gives the average number of demerits characteristic of each grade of Rock Island Sheepswool sponge. Inasmuch as the number of demerits found by actual grading will fluctuate, depending on the lot of sponges and upon the grader, this number is subject to some variation. Accordingly, since round numbers are more convenient to use, the numbers determined by grading were rounded off and rationalized to give the figures shown in the column headed "Demerits recommended to be taken as characteristic."

Table 3.—Average number of demerits characteristic of each grade of Rock Island Sheepswool sponge

Grade	Average demerits found by grading	Demerits recommended to be taken as characteristic	Recommended midpoint to next lower grade
Forms	Number	Number	Number
No. 1	49.5	50	75
No. 2	98.0	100	260
No. 3	432	425	545
Cuts			
No. 1	74.2	75	105
No. 2	142	140	300
No. 3	472	465	565
Forms and Cuts			
No. 4	663	665	765

The following notes were taken during the determination of the values given in table 3.

1. Some faults seldom occur in Rock Island sponges, and the number of demerits rarely approaches the maximum number that is assignable. To omit these infrequently occuring faults or to lower the maximum assignable number of demerits, however, might encourage the offering of sponges inferior in these points in the belief that the points are not important. It is therefore recommended that the faults and the number of demerits be retained as listed in table 1. Buyers are reminded thereby of faults not present in the sponges and accordingly have greater appreciation of the sponges of high quality.

2. A feathery outside structure or "Inshore" type of surface often is accompanied by dirt and weak inside structure.

3. Gurry usually is accompanied by odor. The number of demerits for this fault seems consistently to be higher for sponges from some suppliers than from others.

4. A number of suppliers preferred to submit mixtures, such as "mixed 1 and 2 Cuts," but these were regraded for the purpose of the present work. Sponges of grade No. 4, however, are believed logically to be kept as "mixed Forms and Cuts."

5. The point spread between grades increases rapidly. Thus the desire to allow more tolerance for poorer grades is satisfied.

6. Holes are the most common fault in No. 1 and No. 2 Forms. The same observation applies to Cuts, with the expected increase in number of demerits being found for poor shape. Lack of outside webbing is a common fault in No. 1 and No. 2 Forms. Weak structure is a common fault in No. 3 sponges. No. 4 sponges show an increased trend toward tears and the "inshore" type of surfaces.

Inshore Sheepswool

Table 4 gives the average number of demerits that is characteristic for each grade of Inshore Sheepswool sponge. As compared with Rock Island sponges, the Inshore sponges showed more demerits for inside dirt, weaker structure, feathery surface, and lack of surface webbing. Less gurry was found, and the cuts did not seem to earn as many demerits for poor shape. Tears, when present, appeared to be relatively worse, probably because of the method of harvesting.

Table 4.--Average number of demerits characteristic of each grade of Inshore Sheepswool sponge

Grade	Average demerits found by grading	Demerits recommended to be taken as characteristic	Recommended midpoint to next lower grade
	Number	Number	Number
Forms			
No. 1	99	100	145
No. 2	192	190	335
No. 3	477	480	580
Cuts			
No. 1	137.5	140	190
No. 2	240	235	370
No. 3	495	505	590
Forms and Cuts			
No. 4	672	675	780

Table 5 gives the average number of demerits that is characteristic for each grade of Florida Yellow sponge. Distortions were rare in this sponge. The principal faults encountered were large natural holes, tears, and exterior dirt. This sponge was found to be more uniform than was any other in the following three characteristics: red body, ease of splitting, and stiffness when wet. These characteristics can be used for purposes of identification. A standard number of demerits for each one was given to every Florida Yellow sponge.

Table 5.—Average number of demerits characteristic of each grade of Florida Yellow sponge

Grade	Average demerits found by grading	Demerits recommended to be taken as characteristic	Recommended midpoint to next lower grade
	Number	Number	Number
Forms			
No. 1	504	500	525
No. 2	550	550	630
No. 3	710	710	770
Cuts			
No. 1	526	520	545
No. 2	596	570	650
No. 3	727	730	780
Forms and Cuts			
No. 4	Not available	830	880

Anclote Grass

Table 6 gives the demerits found for the Anclote Grass sponge. Forms were practically nonexistent. This sponge almost always contained some trapped sand or shell particles, was quite tall and irregular in shape, had poor tear strength, contained many large holes, and when not too stiff to be squeezed easily, had a weak inside structure. No new faults became prominent as the grades went down.

Florida Key Wool

Table 7 gives the presently available data on the average number of demerits characteristic of the Florida Key Wool sponge. Not enough samples were received to give a firm average grade rating at this time. Since this sponge showed evidence of Inshore feathers and resembled a cross between Inshore sponges and Mediterranean sponges, ratings for Inshore sponges were used tentatively as a guide. The

Table 6.—Average number of demerits characteristic of each grade of Anclote Grass sponge

Grade	Average demerits found by grading	Demerits recommended to be taken as characteristic	Recommended midpoint to next lower grade
	Number	Number	Number
Cuts			
No. 1	Not available	670	680
No. 2	690	690	755
No. 3	808	820	865
No. 4	912	910	950

Table 7.—Average number of demerits characteristic of each grade of Florida Key Wool sponge

Grade	Average demerits found by grading	Demerits recommended to be taken as characteristic	Recommended midpoint to next lower grade
	Number	Number	Number
Forms			
No. 1	Not available	100	170
No. 2	255	240	355
No. 3	441	470	575
Cuts			
No. 1	Not available	140	220
No. 2	344	300	395
No. 3	449	490	585
Forms and Cuts			
No. 4	655	680	775

samples of the Florida Key Wool sponge had a relatively weak inside structure, lacked a fair amount of surface webbing, had a relatively large number of holes 1/8 to 1/4 inch in diameter, and tended to be flatter on top than is the typical sheepswool sponge. Many of the Florida Key Wool sponges split easily.

Hudson Grass

Table 8 gives the number of demerits that is characteristic of each grade of Hudson Grass sponge. This sponge shows variations approaching the Anclote sponge. It also approaches the Florida Yellow sponge in inside dense structure, but the outside invariably is soft because of the presence of 1/4 inch or more of bridged fibers that vary from individual curly hairs to branched tufts resembling feathers. These tufts are more highly branched or less clumped than are those of Inshore sponges. When wet, the Hudson Grass sponge is stiffer under light pressure than is the Anclote sponge, but it is softer than is the Anclote sponge under heavy pressure. In this property, it resembles the Florida Yellow sponge. It generally is thicker than is the same width of an Anclote sponge, and it has been given a plus credit for the soft outside structure as compared with that of the Anclote sponge. The Hudson Grass sponge tends to hold much sand and shell in the lower grades, often is torn, is split fairly easily, tends to be brittle, drains out a fair amount of water on being tipped, and shows more holes as the grades go down.

Table 8.—Average number of demerits characteristic of each grade of Hudson Grass sponge

Grade	Average demerits found by grading	Demerits recommended to be taken as characteristic	Recommended midpoint to next lower grade
	Number	Number	Number
Cuts			
No. 1	636	640	655
No. 2	672	670	745
No. 3	789	820	855
No. 4	Not available	890	960

Mediterranean Bengasi

Table 9 gives the number of demerits that is characteristic for each grade of Mediterranean Bengasi sponge. As compared with the Rock Island sponge, the Mediterranean Bengasi sponge, in general, was paler, was more rounded, was flatter, held more water per unit volume, was less compressible, was less elastic, was more readily split, recovered its shape more slowly after being pressed, contained more small holes, contained less surface webbing, and had more discoloration. No new fault became particularly prominent as the grades went down.

Table 9.—Average number of demerits characteristic of each grade of Mediterranean Bengasi sponge

Grade	Average demerits found by grading	Demerits recommended to be taken as characteristic	Recommended midpoint to next lower grade
	Number	Number	Number
Forms			
No. 1	277	280	380
No. 2	475	480	555
No. 3	642	630	665
No. 4	680	700	735
Cuts			
No. 1	543	540	615
No. 2	685	690	735
No. 3	728	780	835

Mediterranean Deepwater

Table 10 gives the average number of demerits characteristic of each grade of Mediterranean Deepwater sponge. This sponge was similar in most properties to the Bengasi Mediterranean sponge. The Deepwater sponge held less water, however, and was much softer when wet. It therefore released more water and was easier to clean. It was less elastic and regained its shape more slowly, and had a weaker inside structure because of greater porosity.

Cuban Sheepswool

The Cuban Sheepswool or Sea Wool sponges inspected were a mixture of Cuts, and no Forms were present. In fact, most of the samples were too tall to be classified as forms. Only one No. 4 Cut, however, was in the lot, and most of the samples were No. 2.Cuts. The samples gave off some odor, were low in outside webbing, and had many small holes. Recommendations as to the number of demerits were influenced by the numbers assigned to the Mediterranean sponges, which the Cuban Sheepswool sponge resembles. Except for No. 2 Cuts, which were available for inspection in quantity, the numbers of demerits shown in table 11 is tentative, since they require the inspection of larger samples for confirmation.

Table 10.--Average number of demerits characteristic of each grade of Mediterranean Deepwater sponge

Grade	Average demerits found by grading	Demerits recommended to be taken as characteristic	Recommended midpoint to next lower grade
	Number	Number	Number
Forms			
No. 1	352	350	440
No. 2	542	530	580
No. 3	664	630	675
Cuts			
No. 1	543	580	645
No. 2	698	710	755
No. 3	775	800	845
Forms and Cuts			
No. 4	717	720	850

Table 11.--Average number of demerits characteristic of each grade of Cuban Sheepswool sponge

Grade	Average demerits found by grading	Demerits recommended to be taken as characteristic	Recommended midpoint to next lower grade
	Number	Number	Number
Forms			
No. 1	Not available	300	375
No. 2	Not available	450	525
No. 3	Not available	600	750
Cuts			
No. 1	466	460	505
No. 2	554	550	650
No. 3	746	750	825
Forms and Cuts			
No. 4	925	900	950

1/ Except for No. 2 cuts, these figures are tentative because they require larger samples for confirmation.

GRADING STANDARDS AND PRICES

A study of sponge prices during the fall of 1955 showed that the increase in price with size followed a fairly straight line for each type and grade of sponge, as is idealized in figure 9 on page 15. Since a sponge contains marketable material proportional to its volume, it might be expected that the price would increase as the third power of the diameter. There was a slight upward curvature with increased diameter for some grades, but in general, it appeared that larger sizes must be increasingly difficult to sell, for the sponges were sold proportional to the first power of the diameter rather than to the third power. The relationship between the weight of the Rock Island Sheepswool sponge--expressed as the number of sponges per pound --and the diameter of the sponge is given in table 12.

If it were not for the cost of the labor, it would appear to be advantageous to make Cuts of the larger sizes, since the smallest size--4-1/2 to 5 inches--appears to bring a premium price. Although the demand may be larger for the small sponges, the trade hesitates to handle them because collection or possession of any uncleaned sponge less than 5 inches in diameter is illegal. Fear has been expressed that it may not be generally known that there is appreciable shrinkage between the size of the live sponge and the size of the resulting cleaned sponge.

Using the slope of the lines obtained as in figure 9, one finds that each type and grade of sponge bears a definite ratio by price to the other sponges of corresponding size. For instance, Florida Yellow No. 1 Forms sell at about half the price of the corresponding Rock Island Sheepswool sponge.

When a particular grade of sponge is in short supply, there is a tendency to broaden the grading range by including grades both above and below. The average value--in this case, the average number of demerits--is still close, however, to the previous one. This tendency is entirely different from the one shown when all sponges were scarce during the last war, which was to raise prices and to lower grades. The present system of demerits, employing dimensionless units as it does, would forestall such a trend.

Table 12.—Relationship between the diameter of Rock Island Sheepswool sponges and their approximate weight

Diameter of sponge	Weight of sponge
Inches	No. per lb.
10½ - 11	2
10 - 10½	2 - 3
9½ - 10	3
9 - 9½	3 - 4
8½ - 9	4
8 - 8½	4 - 6
7½ - 8	6
7 - 7½	6 - 8
6½ - 7	8 - 10
6 - 6½	10 - 12
5½ - 6	12 - 16
5 - 5½	16 - 20
4½ - 5*	20 - 25
4 - 4½	25 - 30
3½ - 4*	30 - 35

* Except for shrinkage effects, forms would not appear.

QUANTITATIVE TESTS

Four quantitative tests are discussed in this section: water test, abrasion test, cleanliness test, and density test.

Water Test

The following water properties of sponges were quantitatively determined:

1. K_{wh} - water-holding power
2. K_{sw} - squeezed wetness
3. K_c - cleanability
4. K_s - stiffness
5. K_e - elasticity
6. K_{sr} - shape recovery

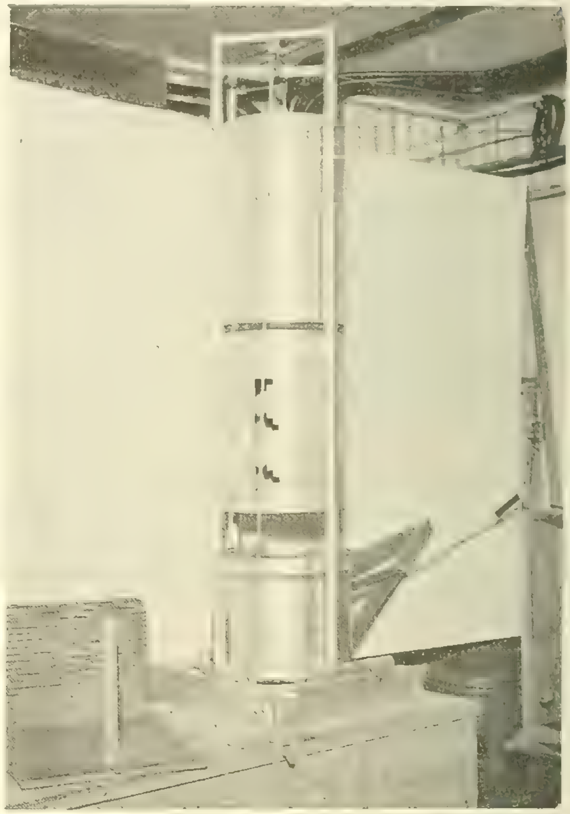


Figure 10.—Wet test equipment.

These properties are expressed by mathematical symbols—K_{wh}, K_{sw} and so on—because all are calculated values that are computed from measurements made on the sponge. These measurements were as follows:

- V - Bulk volume of sponge.
- W_h - Volume of water absorbed.
- W_{ht} - Volume of water absorbed after sponge has been tipped.
- W_r - Volume of water remaining after sponge has been pressed.
- H_s - Height of uncompressed sponge.
- H_c - Height of compressed sponge.
- H_r - Height immediately after pressure is released.
- H_p - Height 2 minutes after pressure is released.

The device used for obtaining these measurements is shown in figure 10. This device consists of three concentric cans supported, one above the other, by a framework of three pipes welded together in such a manner as to form a triangular tower 4-1/2 feet high. A pulley device is attached to the top of the tower for raising and lowering the top can.

Bottom can.—The bottom can, approximately 12 inches in diameter by 13 inches high, is essentially a reservoir for holding a measured volume of water. Connected to the bottom of the can is a pipe. By means of rubber tubing, this pipe leads to a piece of glass tubing that is held by clips on to a support fastened firmly to the can and that is used as a gauge to determine changes in the volume of water contained in the can.

In figure 10, this glass tubing is shown protruding at an angle from the lower right side of the picture. This tube will indicate a change of 60 cubic inches in the volume of water. It slopes upward with a rise of 1 inch in 10 horizontal inches, which slope permits a sensitive reading of any change in the volume. The midpoint of the tube corresponds to a height of water in the can of about 9 inches.

A scale for determining changes in the volume of water in the can is made from a small strip of soft copper. The ends of the strip are cut and bent into clips so that the scale can be hung on the glass tube and moved along as desired. Four calibrated reference lines are scratched onto the scale. Additional lines are added and so spaced that the scale covers 60 cubic inches and indicates major divisions at each cubic inch of volume change in the main tank.

Vibrations retard the reading of the gauge. The stand therefore must be braced well and the tank bearing the gauge must be fastened firmly to a heavy table. A small level is attached to the arm that holds the gauge so any displacement of the gauge may be corrected.

Middle can.—The middle can is essentially a metal measuring basket. It is 14 inches high and 10-1/2 inches in diameter. Serving as the bottom is a heavy, 1/4-inch thick iron plate, which has holes bored in concentric circles, the radii of which differ consecutively in length by 1/2-inch.

The basket contains two vertical slots cut into the opposite sides in a sawtooth pattern with a tooth for every half inch of height. By sighting across the teeth, one can estimate the height of a sponge placed in the basket.

Welded onto the side of the basket near the top are three small lugs. These lugs fit into slots cut into the upright supporting pipes and permit the basket to travel up and down without rotating. The upper ends of the slots are cut and widened in such a manner that by a slight twist of the basket, the lugs have a support that enables the basket to be held suspended in place in a "rest" position.

Top can.—The top can is essentially a vessel for exerting pressure on a sponge held in the middle can. This top can is 14 inches high and of such a diameter as to fit closely inside the middle can. A loose handle is attached inside the top rim. The can is lifted up and down by means of rope and pulleys attached to the top of the supporting frame. The pressure exerted is variable by means of the amount of water or number of weights placed in the can.

Measuring board.—In addition to the device described above, a measuring board was used for determining the size of the sponges. This board, which is shown in the lower left hand corner of figure 10, consists of two boards, each of which is one foot square and is nailed at right angles to the other. In addition, a vertical strip of aluminum is nailed to the front of the base. The aluminum strip bears a half-inch scale; the back vertical board bears horizontal lines marked in divisions of one-half inch; and the bottom board bears concentric circles one-half inch apart. All scales are suitably numbered.

Procedure used in water tests.—The following procedure is used in the water tests:

1. Fill the bottom can with water until the level in the slanting glass tube reaches the midpoint.

2. Blow gently into the end of the glass tube several times to prevent any clinging of the water to the glass and resulting inaccuracy in the determination of the level of water.

3. If difficulty is encountered in determining the level, poke a few grains of surface-active material, such as Dreft, into the tube with a wire.

4. Immerse the middle can, or measuring basket, in the water in the bottom can to wet the measuring basket.

5. Lift the basket out of the water up to the rest position and allow any water present to drain from the basket.

6. Move the copper scale to indicate the starting level of water in the can.

7. Place a sponge in the basket and immerse the basket and sponge in the water.

8. Press the sponge against the bottom of the basket with a smooth rod (not hard) until no more bubbles of air rise from the sponge.

9. Lift the basket from the water to the rest position and let the free water drain back into the bottom can.

10. Read the copper gauge to determine the volume of water absorbed by the sponge and record this volume as W_h, the water holding power.

11. If the sponge is a Grass sponge, tip it on end, lean it against the side of the basket to drain, and record the resulting final volume as W_{ht} for the Grass sponge.

12. Press the sponge well to remove water, and transfer the sponge to the measuring board.

13. Read the smallest and largest diameters of the sponge by means of the circles on the bottom of the board.

14. Read the height of the sponge by means of the half-inch marks on the vertical strip of aluminum and the horizontal lines marked on the vertical back board.

15. Record the height of the sponge as H_s, the height of the uncompressed sponge.

16. Multiply the smallest diameter by the largest diameter and then by 0.4; that is, $D_s \times D_l \times 0.4$. (Note: The answer gives the weight in pounds needed to apply a pressure of 1/2-pound per square inch to the sponge.)

17. Multiply the answer obtained in step 16 by the height of the sponge and then by 1.3; that is $(D_s \times D_l \times 0.4) \times H_s \times 1.3$. (Note: the product obtained is approximately equal to $\frac{\pi D^3}{6}$.)

18. Record the answer obtained in step 17 as being V, the bulk volume of the sponge.

19. Subtract the weight of the top can or pressure vessel from the answer obtained in step 16.

20. Add to the pressure vessel a weight in pounds equal to the answer obtained in step 19.

21. Place the sponge in the measuring basket.

22. Lower the measuring basket into the water, submerge the sponge, and press out all the bubbles again.

23. Raise the measuring basket to the rest position.

24. Slowly lower the pressure vessel onto the sponge.

25. Determine the volume of water remaining in the sponge by reading the copper gauge.

26. Record the answer obtained in step 25 as being W_r, the water remaining in a sponge when a pressure of 1/2-pound per square inch is applied.

27. Observe the height of the sponge and record the height as being H_c, the compressed height.

28. Quickly raise the pressure vessel from the sponge and immediately observe the height of the sponge.

29. Record this height at being H_r.

30. Wait 2 minutes and again observe the height.

31. Record this height as being H_p, the height corresponding to the permanent set.

Calculation of water properties.--The data obtained by the procedure described above were used to calculate the following quantitative values:

A. Water-holding power. This gives the volume of water absorbed as a percentage of the bulk volume of the sponge. Water-holding power is the volume of the sponge divided into 100 times the volume of water absorbed: $K_{wh} = 100\ W_h/V$

B. Squeezed wetness. This gives the water remaining after pressing as a percentage of the bulk volume of the sponge. Squeezed wetness is the volume of the sponge divided into 100 times the volume of water remaining in the sponge after the sponge has been subjected to a pressure of 1/2-pound per square inch: $K_{sw} = 100\ W_r/V$

C. Cleanability. This gives the ability of the user to remove the dirty water from the sponge as a percentage of the water left in the sponge after pressing. It is the volume of water left in the sponge divided into 100 times the volume of water squeezed out of it: $K_c = 100\ (W_h - W_r)/W_r$

D. Stiffness. This gives the difficulty in compressing the sponge as a percentage of the height of the uncompressed sponge. Stiffness is this height divided into 100 times the new height during compressing: $K_s = 100\ H_c/H_s$

E. Elasticity. This gives the ability of the sponge to return immediately to its original shape as a percentage of the height of the uncompressed sponge. Elasticity is this height divided into 100 times the immediate height after the pressure is released: $K_e = 100\ H_r/H_s$

F. Shape recovery. This gives the ability of the sponge to return, 2 minutes after the pressure on the sponge is released, to its original shape as a percentage of the height of the uncompressed sponge. Shape recovery is this height divided into 100 times the height 2 minutes after the pressure is released: $K_{sr} = 100\ H_p/H_s$

Water-test conclusions.--Standard statistical techniques (Snedecor 1946) were used in arriving at the conclusions that follow on the water tests.

A. Water-holding power, as shown by table 13, is least for the Anclote Grass and the Hudson Grass sponges. Although the average for the Hudson Grass sponge is higher than is that for the Anclote Grass sponge, the fidicial limits for these two overlap. A superiority therefore cannot be claimed for the Hudson Grass sponge on the basis of the present size of samples.[1]

[1] Mathematical statistics are based on probability and the larger the number of observations, the greater is our confidence in our conclusions and the narrower we can set our fiducial limits. We might point out, however, that the mathematics are such that to narrow appreciably the fiducial limits reported here would require much larger samples, which would greatly increase the cost of the tests without adding proportionately to additional knowledge.

The same is true for the next distinctly more superior group. More tests, for instance, might show some significant difference between Florida Yellow, Inshore, Mediterranean Deepwater, and Rock Island sponges, but with the present data from a relatively limited number of samples, the only conclusions are that in water-holding power, these sponges overlap in individuals even though they are all superior to the Grass sponges. Mediterranean Bengasi sponges, with the highest values, within 95 percent statistical probability, definitely hold more water per unit volume than do the Inshore, Deepwater, and Rock Island sponges, but the Bengasi sponges cannot be said to be more absorbent than are the Florida Yellow sponges. This test, in itself, is not too important. A brick made with the proper pore size, for instance, theoretically can hold more water per unit volume than can any sponge.

Table 13.--Water-holding power

Type of sponge	Number of sponges tested	Average	Standard deviation[1]	Fiducial limits[2]
		Percent	Percent	Percent
Mediterranean Bengasi	25	53.6	5.4	51.4-55.8
Florida Yellow	24	49.0	8.5	45.4-52.6
Inshore Sheepswool	26	46.2	7.4	43.2-49.2
Mediterranean Deepwater	28	45.9	7.0	43.2-48.6
Rock Island Sheepswool	28	43.8	9.9	39.9-47.6
Hudson Grass	25	37.8	2.6	36.7-38.8
Anclote Grass	24	36.5	4.9	34.5-38.6

1/This column shows the variability in water-holding power among sponges of a given type. The larger the number in this column, the greater the variability in water-holding power.

2/This column indicates the limits within which the averages of the samples will fall 95 times out of 100. With Mediterranean Bengasi sponges, for example, the average water-holding power will be expected to fall between 51.4 and 55.8 percent in 95 out of 100 samples of 25 sponges each.

B. Squeezed wetness, the next test to be considered in the order of testing, shows (table 14) that with 1/2-pound per square inch pressure, the Florida Yellow sponge releases the least water. No distinction can be made statistically among the other types of sponges tested.

Table 14.—Squeezed wetness

Type of sponge	Number of sponges tested	Average	Standard deviation	Fiducial limits
		Percent	Percent	Percent
Florida Yellow	24	44.4	8.7	40.8-48.1
Anclote Grass	24	31.6	13.8	25.8-37.5
Rock Island Sheepswool	28	29.8	7.3	28.0-33.7
Hudson Grass	25	30.8	5.2	28.7-33.0
Mediterranean Bengasi	25	35.7	6.5	25.0-37.5
Inshore Sheepswool	26	28.6	5.1	26.6-30.7
Mediterranean Deepwater	28	27.6	5.5	25.5-29.8

C. Cleanability is the practical result of the two preceding tests. Inshore and the Deepwater Mediterranean sponges, owing to their combined absorbency and softness, can be washed out faster with the same amount of squeezing than can any of the other sponges. The statistical analysis (table 15) shows that Rock Island and Mediterranean Bengasi sponges

Table 15.—Cleanability

Type of sponge	Number of sponges tested	Average	Standard deviation	Fiducial limits
		Percent	Percent	Percent
Mediterranean Deepwater	28	68.5	21.0	60.4-76.7
Inshore Sheepswool	26	62.6	23.1	53.2-71.9
Rock Island Sheepswool	28	48.1	21.8	39.6-56.5
Mediterranean Bengasi	25	46.8	5.8	44.4-49.
Hudson Grass	25	23.1	14.9	17.0-29.3
Florida Yellow	24	20.6	8.9	16.5-24.8
Anclote Grass	24	15.8	10.7	11.3-20.3

are not as high in this test as are the Mediterranean Deepwater sponges, but with the number of samples run, there was no significant difference between the Inshore and Rock Island sponges. The Inshore, Rock Island, and Mediterranean sponges, however, have a higher cleanability than have the remaining three. These three--Hudson Grass, Florida Yellow, and Anclote Grass--give practically the same low value of cleanability. Again, it must be remembered that other factors enter into the choice of a sponge. Grass sponges, for instance, drain out a lot more water when tipped on end. This property would apparently make them easier to clean, but the same modification of the test would work against them in water-holding power. The drained water would drastically reduce the maximum amount of water that they could be said to hold.

D. Stiffness tests (table 16) indicate that there are three groups statistically different from each other. The Mediterranean Deepwater are the least stiff (in other words, the softest), followed closely by a tight group composed of Inshore, Rock Island, and Mediterranean Bengasi. Bridging the gap, but not distinctly different from the stiffest group, is the Anclote Grass sponge. The Florida Yellow and the Hudson Grass sponges are the other stiff sponges.

Table 16.--Stiffness

Type of sponge	Number of sponges tested	Average	Standard deviation	Fiducial limits
		Percent	Percent	Percent
Hudson Grass	25	40.7	15.8	34.2-47.2
Florida Yellow	24	41.1	10.6	36.7-45.6
Anclote Grass	24	32.1	13.2	26.5-37.7
Mediterranean Bengasi	25	22.6	5.7	21. -25.
Rock Island Sheepswool	28	20.9	3.6	19.5-22.3
Inshore Sheepswool	26	20.6	2.7	19.5-21.7
Mediterranean Deepwater	28	16.6	4.5	14.9-18.4

E. Elasticity is important. Whether the sponge be stiff or soft, the user wants it to regain most of its shape immediately. Under the carefully controlled conditions of these tests, both soft and stiff sponges can be said to have the same elasticity with the exception of both of the Mediterranean sponges (table 17); for instance, Inshore, Rock Island, Florida Yellow, and Anclote Grass sponges all have the same high elasticity. Only the Hudson sponges recover more of their height immediately. The Mediterranean Deepwater sponges are the least elastic, with the Bengasi having a definite superiority over the Deepwater sponges. Elasticity may be an important property in determining the preference for the domestic sponges by several of the trade groups, such as window washers.

Table 17.--Elasticity

Type of sponge	Number of sponges tested	Average	Standard deviation	Fiducial limits
		Percent	Percent	Percent
Hudson Grass	25	97.6	2.4	96.6-98.6
Inshore Sheepswool	26	84.3	12.4	80.4-96.5
Florida Yellow	24	95.2	2.9	94.0-96.4
Anclote Grass	24	94.9	3.4	93.4-96.3
Mediterranean Bengasi	25	78.1	6.4	75.5-96.3
Rock Island Sheepswool	28	91.5	9.4	87.8-95.1
Mediterranean Deepwater	28	69.8	11.8	62.2-74.4

F. Shape-recovery testing allows the sponge 2 minutes to recover its original size. If the sponge does not spring back immediately on repeated fast squeezing during washing, however, this slow spring-back does not mean that a few minutes of soaking will still leave it without good recovery of shape. Nor does a slow return at the end of 2 minutes mean that the sponge has become "dead" or "not springy." None of the sponges are really poor in this respect at the end of 2 minutes, and it was observed that with repeated wettings, the slow shape recovery of the Mediterranean Deepwater sponges (table 18) is not progressive or ever permanent. This test cannot therefore be called a "permanent set" test in the scientific meaning of the words. By accidentally drying some sponges at too high a temperature and also by squeezing sponges through steel rolls at high pressure, the author obtained sponges that were "dead." In short, they took such a high permanent set that they resembled a wet cloth and were practically worthless. Aside from the Deepwater Mediterranean, all the sponges had a high recovery of shape in 2 minutes.

Summary of water properties.—A summary of water properties does not reveal any one outstanding type of natural sponge, but these quantitative tests (the first ever published) should enable a buyer to pick the type of sponge he needs for a particular property. These tests agree well with the sensory tests that have been used for many years, in these particulars:

1. The choice of natural sponges for commercialization is verified in that all show useful properties. No one sponge is superior in enough properties to justify the exclusion of others from the trade.

2. The softness of the Mediterranean Deepwater sponges and the stiffness of the Grass and Florida Yellow sponges are confirmed.

Table 18.--Shape recovery

Type of sponge	Number of sponges tested	Average	Standard deviation	Fiducial limits
		Percent	Percent	Percent
Hudson Grass	25	99.5	1.2	99.0-100
Anclote Grass	24	98.1	2.5	97.1-99.2
Mediterranean Bengasi	25	91.0	9.2	87.2-99.2
Florida Yellow	24	97.8	1.6	97.2- 98.5
Rock Island Sheepswool	28	94.9	9.3	91.3- 98.5
Inshore Sheepswool	26	93.3	7.9	90.1- 96.4
Mediterranean Deepwater	28	79.1	10.0	75.2- 83.0

3. The difficulty in cleaning the Grass and the Florida Yellow sponges is confirmed.

4. The low absorbency of the Grass sponges is confirmed. The high absorbency of the Bengasi sponges, however, was not known, or at least not publicized in the domestic trade. It is interesting that the Florida Yellow sponges, however, are statistically not any less absorbent.

5. The low elasticity and shape recovery of the Mediterranean Deepwater sponge, with the Mediterranean Bengasi sponge being close behind in elasticity, are shown.

6. The high shape recovery of the Hudson Grass sponge, with the Anclote Grass, Florida Yellow, and Rock Island sponges in the next close group, also is shown.

Field testing.--Originally, it was hoped that a simple field tester could be devised to make use of the important quantitative findings based on wet testing, as described above. If in the future, this test still is thought to be important, it is suggested that a first trial could be made by using a type of pliers that would bear two porous plates and a standardized spring. The spring could be set in notches corresponding to a definite pressure per square inch for the average diameter (in other words, area) of the sponge, and the spring could be cocked with the plier handles. The procedure in this test could be as follows: (1) The sponge is wet in a standard volume of water in a calibrated vessel and placed between the plates. (2) The volume of water is observed in the vessel. (3) The spring is released so that the sponge returns water to the vessel under a standard pressure per square inch exerted by the spring. And (4) The volume of water in the vessel is read again. A table would allow reading without any calculation of the resulting absorptivity and squeezed wetness. Stiffness and shape recovery could be calculated from heights observed at the same time, but the technique required might be too demanding for the results obtained. Even the reading of the volumes in the vessel might require a training program.

Abrasion or Wear Tests

The equipment used in the abrasion tests was based on a Paint Washability and Abrasion Machine, Model Number 105, obtainable through the Gardner Laboratory, Bethesda, Md. This machine (figure 11) is capable of recording the number of times it rubs a sample across a standard surface either with or without the presence of a liquid. It was designed to rub a standard sponge or abrasive block across a painted surface until the paint shows signs of wear, thereby allowing the comparison of paints under standard conditions. The apparatus and operations were modified for use with sponges by:

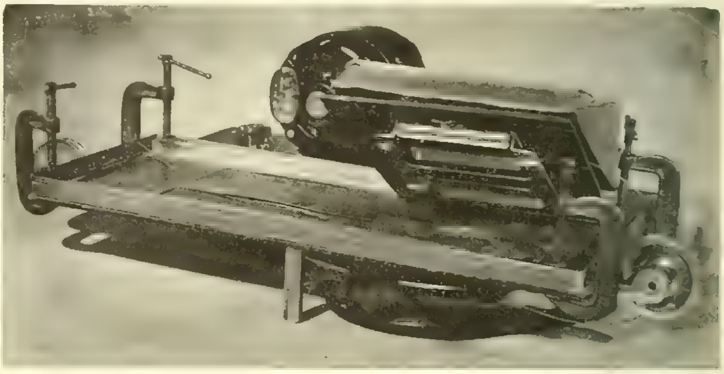


Figure 11.—Abrasion test equipment

1. Using a standard sheet of wet-dry silicon carbide paper (Tri-M-ite, 400A grit) instead of a painted surface, and changing it after each set of sponges had been tested. Reuse of the paper gave poor results.

2. Shortening the stroke of the machine to 10 inches so that it did not run off the ends of the standard-size silicon carbide paper ($8\frac{1}{2}$ x 11 inches).

3. Tilting the machine a few degrees so that water could be run across the abrasive surface at the rate of about one cubic centimeter every 5 seconds.

4. Holding the silicon carbide paper tightly against the bottom of the pan with a metal plate bearing rubbing slots so that the paper did not move and wrinkle.

5. Modifying the frame, which holds two samples at a time, so that the boxes that hold the blocks bearing the sponges are held loosely in the frame. This modification allows the sample to be pushed rather than pulled, thereby reducing the tendency of the front of the sponge sample to dip and dig into the paper. If the sponge is allowed

to dip and dig, the front edge of it wears off rapidly. The frame furnished with the equipment was attached to the sample boxes as intended by the manufacturer, but around this frame was placed a Formica rectangle that received the pull from wires leading to a reciprocating arm. This rectangle extended over the edges of the water pan upon which it slid in slots cut in the Formica. Wet Formica has a very low coefficient of friction. Since the rectangle could not dip and since it pushed the frame carrying the sample boxes at a point below the usual center of rotation at which they dipped before the change in design was made, the dipping was practically eliminated. Accordingly, the sponge samples wore evenly.

6. The samples were wired front and back to zinc diecast blocks, which originally were the blocks bearing the bristles intended to scrub paint samples.

7. The amount of wet sponge extending below the edge of each box varied with the softness of the sponge, in spite of the fact that all sponges were cut wet to 1½" x 1½" x 3½" standard size. In a few cases, extra soft sponges still allowed the box to hit the abrasive paper before the test was finished. In these cases, strips of plastic were inserted behind the sponge holder in the box. This insertion of plastic was particularly necessary when a soft sample was being tested along side of a stiff sample.

8. Standardizing on sponge samples cut from the top surface so that the samples were representative of the sponge but did not contain any large holes. The samples were tested with the surface against the emery paper and usually were tested with one sample from one sponge and with the other sample from another sponge, so that any large differences between different sponges could be detected. The number of strokes varied from 500 to 1500. The machine ran at 60 strokes per minute. By means of weights in a pan attached to the top of the frame fastened to the sample boxes, the pressure on the sample could be varied. The initial pressure of 0.22 pounds per square inch was not changed, since all the experimenter's time was spent in trying to get more accurate data. The sponges travelled over a path of 10 inches and were 3½" long, which left an actual rubbing path of 6½ inches, or a total travel over paper, in 1000 strokes, of 542 feet—or more than a tenth of a mile.

Procedure.—The data were obtained as follows: The wet sponge was cut as described above, dried at 140°-160°F., weighed warm to offset the rapid absorption of moisture from the air (a Rock Island sponge, when exposed to 100 percent humidity, picked up 41 percent moisture), rewet, wired to the block, abraded, and redried along with any large pieces of sponge that may have been torn off during the test. The wear was calculated to a standard 1000 strokes for comparison.

Abrasion results.—The data are given in figure 12. In this figure, the length of the line represents the spread of values that are characteristic of the given sponge, within the probability chosen for statistical analysis. Since the data were not as accurate as were those for the water tests, an 80 percent probability limit was chosen. In other words, there is only one chance in five that any average sponge of the particular grade chosen will give abrasion losses outside of the range depicted by the line on figure 12 for that sponge. The maximum loss of any sample tested was less than 2 grams from a sponge sample weighing 4.4 grams. Most of the sponges showed a loss of less than 1 gram.

Conclusions on abrasion tests.—More work is needed to correlate the abrasion test with types and grades of sponges. Although there are some trends in the data, this test cannot presently be used to predict sponge wear in actual service.

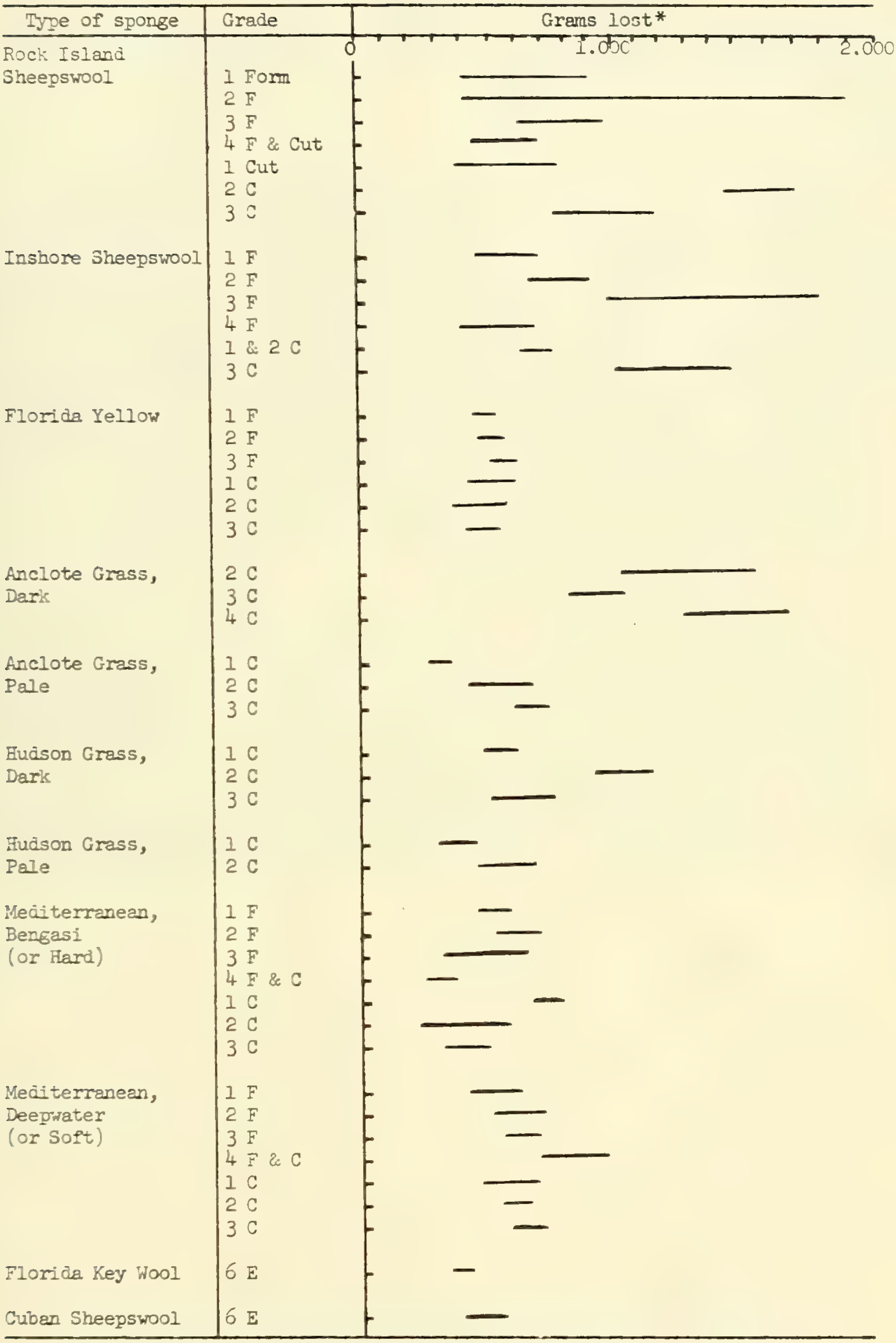
The main trend appearing in the data is for the relatively stiff sponges—Florida Yellow, pale Anclote, and pale Hudson—to give the least abrasion loss, and for the loose-structured sponges—Inshore, Deepwater Mediterranean, dark Hudson, and dark Anclote—to give the most abrasion loss. So few Florida Key and Cuban Sea Wool sponges were available that no conclusions can be drawn regarding them except to say that neither gives high abrasion losses. Aside from the relation to variations in bulk density (stiffness and looseness), it appears that the fine structure of all of these sponges has about the same rate of wear.

The test does not reveal a consistent progression from No. 1 through No. 4 grades of sponges. The explanation for this fact is that the distinctions between grade numbers have been on the basis of faults that would not have much effect in a small sample. Furthermore, Forms differ from Cuts mainly in shape, which difference also would not become evident in the small samples used in this test. Thus, a more realistic wear test should be based on using the whole sponge, rather than on using $1\frac{1}{2}$" x $1\frac{1}{2}$" x $3\frac{1}{2}$" samples, so that such defects as large holes and weak inside structure would have more chance to affect the results of the wear test. Bulk density also is worthy of investigation.

Cleanliness Test

On the basis of studies reported in table 19 (page 57), it is felt that no natural sponge should contain more than 10 percent of material that can be removed by thorough washing. Since the determination of the amount of material removable by washing requires the use of an analytical balance, in most cases a qualitative test may have to be substituted. The following is suggested: Dampen the sponge with a minimum of water and do not rinse. Squeeze out a few drops onto a piece of glass. Reject the sponge as unclean if the drops appear to be milky against a dark background, or if on drying, the plate shows

Figure 12.--Natural sponges abrasion loss, statistically reliable within 80 percent probability.



* Per 5.25 square inch for a 0.22 pound per square inch load over 542 foot path on wet 400 A silicon carbide paper.

the presence of a film that is appreciably greater than that left by the pure water. The water squeezed from the sponge should not leave a sticky feeling on the fingers, nor should there be any appreciable smell.

Density Test

The density of the spongin or structural material of sponges was difficult to determine. No matter how finely the samples were divided, they tended still to hold sand particles, which increased their weight, or to hold bubbles, which decreased their weight. Best results were obtained by cutting the sponge into thin slivers, pounding and rolling the slivers between a glass rod and plate in water containing Dreft until the sand was washed out, bringing a Dreft solution suspension of sponge material to a boil (with constant prodding) to remove air bubbles, cooling and examining with a good lens to determine whether further cleaning was needed. The sponge material should not be allowed to drain out any water until the density is determined by displacement in the customary specific-gravity bottles, or the boiling operation will have to be repeated to remove air bubbles. The best tests indicated that the basic material of these sponges had a density of 1.50 grams per cubic centimeter of sponge material.

A more convenient figure, and one that does show some difference between types of sponges and individual sponges, is that of the bulk density. This value is the weight of the sponge converted to grams per cubic centimeter or pounds per cubic foot for the bulk of the sponge. Where cellulose sponges have been manufactured with an unusually low bulk density of 3.26 pounds per cubic foot, and a urethane type sponge possessed a bulk density of 2.60 pounds per cubic foot, the natural sponges treated were of even lower bulk density of about 2 pounds per cubic foot. Not enough figures were obtained to report reliable average values for other than the Rock Island sponge.

Table 19. --Results of washing Rock Island Sheepswool sponges

Kind of sponges	Number of sponges tested	Weight as received	Weight after drying	Moisture content, on dried basis	Weight washed and dry	Material washed out, on dried basis	Volume			Density dry		Wt.ratio, dry, original/clean
							Wet	Dry	Expansion	Uncleaned	Clean	
Grade of 4 to 6 inch sponges, which contained gurry when received	Number	Grams	Grams	Percent	Grams	Percent	Cu. in.	Cu. in.	Percent	G./cu. in.	G./cu. in.	Ratio
No. 1 Forms and Cuts	12	59.3	50.7	17.0	26.8	47.0	43.9	42.8	2.8	1.19	0.627	1.89
No. 2												
Forms*	13	48.0	41.6	15.7	21.2	48.5	50.7	44.5	11.2	0.821	0.477	2.01
Cuts	29	36.7	31.9	15.1	20.3	36.0	42.9	34.2	27.1	0.935	0.594	1.57
No. 3 Forms and Cuts	29	39.3	34.1	15.3	20.8	39.1	41.8	34.5	21.5	0.989	0.603	1.64
No. 4 Forms and Cuts*	21	38.5	32.8	17.3	16.7	48.2	34.7	33.0	10.3	0.995	0.505	1.97
New assorted clean shipment	12	37.5	30.7	22.1	28.6	6.8	-	23.7	-	-	-	1.07

*Number 2 Forms and No. 4 Forms and Cuts were given a more drastic treatment by squeezing water out between steel rolls. Some breakdown was noted.

SELLING BY WEIGHT

Federal Specifications contain information relative to two perimeters of the sponge and relative to the weight of the sponge, either of which information could be used as a basis for the sale of sponges. In the past, sales ordinarily have been made on the basis of weight. Recently, many people in the industry have felt that sales should be on some other basis. The members of the Sponge Exchange, for example, recommend using perimeters (rather than "go-no go" holes) and the writer recommends a simple three-diameter measurement.

The need for the change is well known. In the past, up to 100 percent weight has been added by foreign materials, which not only were troublesome to put into the sponge but had to be removed from it before it could be sold to the ultimate consumer. No one in the trade was mislead by this practice. It was merely a nuisance. Today even with the practice perhaps permanently discontinued, natural sponges still are being offered in an unattractive form that favors the sale of competitive materials in that varying amounts of gurry are left in to increase the weight, which unfortunately results in unpleasant odor, unattractive appearance, and undesirable feel.

The seller caught in the change over to cleaner sponges is faced with the problem of convincing the buyer that these cleaner—and therefore lighter—sponges should sell for more even though they weigh less. Sales by volume or dimensions is the answer. The increased value then is obvious, since the sponges are more pleasing in appearance when well washed. Table 19 gives data illustrating the kind of analysis that would enable the buyer further to recognize the enhanced value of the well-cleaned sponge. The data in table 19 show that the first lot of unwashed sponges contained, on the average, 36 to 48 percent of "gurry," on a dry basis. The second lot of sponges, which was representative of the new voluntary standard, contained only 6.8 percent, on the average. These data indicate that a 10 percent content of material that can be washed out is a reasonable maximum limit.

Another factor that makes dimensions a better criterion than weight as a basis for sales is the fact that a sponge that has been dried picks up moisture rapidly from the air after it has been removed from the drier. Experiments showed that Rock Island sponges soon picked up more than 40 percent of their weight when dried and then put beside a beaker of water in a closed vessel. Under ordinary conditions, these particular sponges contained from 9.5 to 53.5 percent moisture. The latter figure was obtained on the specially washed samples and therefore indicates that the hygroscopic property of the gurry is not the only factor causing the sponges to absorb water from the air. Obviously, sale by weight is inaccurate, since the content of moisture may markedly vary from a dry to a damp day or as a result of the moisture that has been purposely added.

The method of determining diameters recommended by the writer requires only an easily constructed measuring board. (This board was described under water testing.) The sponge, which has been moistened to permit examination for grading, is laid on its broadest side in the center of concentric circles scribed on the base board, the maximum and minimum diameters are noted, and the center height is sighted between the backboard scale and the front half-inch-marked post. A single figure that gives the approximate volume of the sponge can be obtained by dividing the product of the three diameters by two.[1] This method of measurement is faster than is the determination of perimeters with a tape measure, gives one figure instead of two, comes close to the true volume, and avoids inept placing of the tape or pulling it too tightly or too loosely. A wet sponge is easily distorted.

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[1] The volume of a sphere is equal to $\frac{\pi}{6} D^3$. The coefficent $\frac{\pi}{6}$ is to $\frac{3.1}{6}$ which is approximately equal to 1/2 or 0.5. Since the sponge is not truly spherical, the figure 0.5 is close enough to the true value of 0.52.

RECOMMENDATIONS FOR GRADING STANDARDS

The following is a report of a meeting of the Sponge Exchange, held on November 8, 1955 at Tarpon Springs, Florida:

1. Each part of the present "Federal Specification for Sponges, Natural" under the number C-S-631b, June 24, 1941 of the Federal Standard Stock Catalog, Section IV, Part 5, as well as Amendments 1 and 2, was discussed and agreement reached as to recommendation for retainment or modification thereof.

2. On several occasions it was brought out that the members of the Exchange felt that the most important recommendation they wished to make was:

Wherever foreign natural sponges are compared with domestic natural sponges both groups should be treated in exactly the same manner. For instance, in C-S-631b, Paragraph B-1 labeled "Type", Type I and Type XII and Type XIII are considered by some purchasing agents to be approximately equivalent and are so indicated on requests for bids. Since Type XII and Type XIII include both forms and cuts, mixed, while Type I allows only forms to be considered and since cuts are usually accepted as being lower priced than forms, Type I (the domestic) sponges have been unjustly penalized. Obviously "mixed" must be defined as 50-50, etc., for similar reasons.

It was recommended that Type I should, therefore, include cuts and that "mixed" should be defined. In fact, this may have been the original intention of the Specifications since Rock Island sheepswool middle range cuts No. 1 are not listed under any type although both cuts and forms are listed for No. 2 quality. This change should be made as soon as possible.

3. It was recommended that the term "middle range" be dropped. This term has no definite meaning in fathoms, it is impossible to certify and is an unnecessary limitation, since some sponges in this approximate 4-9 fathom area are not sufficiently firm, while some sponges from other depths often are of as good or better quality. In other words, sponges are graded now by more significant qualities than the areas from which they are taken. The acceptance of the new term "inshore type" eliminates the need for the exclusive term "middle range."

4. Much discussion took place as to the significance of "Rock Island" and other area designations. Although it was agreed that grading is done now by more significant quality designations than by areas, it was felt that the term "Rock Island Sheepswool" has become an unofficial trademark of a desireable type of sponge and should be retained in entirety.

5. The "inshore type," mentioned above was recommended for inclusion in the grading standards. In general this is a type found at all depths and easily recognized by its shagginess and looser structure. This is believed to be due to a faster rate of growth, which is common to but not limited to areas near the mouths of streams.

6. Also discussed were the Cuban natural sponges. Until more than one type of these become commercially available and significant, a more specific designation cannot be made than that under Type XIII.

7. Also recommended, in view of the admitted difficulties encountered in writing a non-controversial description of grading, is the hiring by the Government of men competent in grading. A Government employee in Tarpon Springs to certify shipments would be the simplest solution.

8. After much discussion of the complications involved in carrying out this last recommendation, the members of the Exchange listened to Dr. Bennett's description of the scientific tests that he was making and decided that these should answer the purpose. Dr. Bennett reminded them that such tests of absorption, cleanliness, abrasion resistance, resiliency, etc., would have to be accompanied by some descriptive matter, might have to be run in a reasonably equipped laboratory, would have to be run on a fairly large sampling of any one lot, and might not group the sponges in exactly the same grade classes as the presently accepted sensory tests numbers. Also, he pointed out that recommendations from himself and from the Exchange could not constitute a first draft of new grading standards, but would be of definite assistance to the Government in setting up these standards for their own purchasing agents and for only the Government at present.

9. After comparison of the weight-size relationships that existed before World War II, during the war, and in the present voluntary well-washed standards accepted by most of the industry, it was recommended that Federal Specification C-S-631b, Paragraph 1-3 be recommended for universal acceptance, and that the then superfluous columns of "Number of Sponges per pound" be eliminated from the Specifications. It was

believed that the grading work in progress on cleanliness would help to eliminate the need for the weight standards. The present perimeter measurements were preferred over the three-axis method described by Dr. Bennett. It was agreed that the present practice of marketing sponges by size is to be recommended. It was agreed that the present practice of checking size by only one "go-no-go" ring is inadequate and that perimeters should be used instead.

10. In more detail, it was recommended that the following changes be made in the Federal Specifications C-S-631b. Parts not mentioned are acceptable as they stand. A section should be added to clarify grading by tests similar to those being developed by Dr. Bennett. Types may then eventually reach a status of secondary importance.

It is recommended that Federal Specifications C-S-631b should be changed to read:

B-1-Type I - Rock Island Sheepswool, No. 1 forms and cuts mixed with not less than 33% forms.

Type II - Florida key sheepswool, No. 1 forms and cuts mixed with not less than 33% forms.

Type III - Florida yellow, No. 1 forms and cuts mixed with not less than 33% forms.

Type VI - Rock Island sheepswool, No. 2 forms and cuts mixed with not less than 33% forms.

Type VII - Florida key sheepswool, No. 2 forms and cuts mixed with not less than 33% forms.

Type VIII - Florida yellow, No. 2 forms and cuts mixed with not less than 33% forms.

Type IX, X, XI to be deleted.

Type XII - Change "honeycomb" to Bengasi, No. 1 forms and cuts mixed with not less than 33% forms.

Type XIII - Cuban sheepswool, No. 1 forms and cuts mixed with not less than 33% forms.

Type XIV - Mediterranean Bengasi, No. 2 forms and cuts mixed with not less than 33% forms.

Type XV - Mediterranean deep water, No. 1 forms and cuts mixed with not less than 33% forms.

Type XVI - Mediterranean deep water, No. 2 forms and cuts mixed with not less than 33% forms.

Type XVII - Florida sheepswool inshore type, No. 2 forms and cuts mixed with not less than 33% forms.

Type XVIII - Anclote grass, No. 1 forms and cuts mixed with not less than 33% forms.

Type XIX - Anclote grass, No. 2 forms and cuts mixed with not less than 33% forms.

Type XX - Hudson grass, No. 1 forms and cuts mixed with not less than 33% forms.

Type XXI - Hudson grass, No. 2 forms and cuts mixed with not less than 33% forms.

E. Change type descriptions to agree with the above recommendations. Delete the columns headed "Number of Sponges per Pound". Make all size alphabet classifications consistent. For instance size D should be "36" average, minimum" for all types of sponges. Add proportional size classifications to increase the number of sizes to 8 in Types I, III and VIII.

F-3a. In the last sentence the wording allows one perimeter to be taken over a small end. It would be clearer if these words were added to the sentence: "with the axis of intersection passing through the approximate center of the sponge."

G-1a. In view of the prevailing methods of buying and the insurmountable obstacles offered when sponges are marketed on a weight basis, it is recommended that the phrase "50 to 57 pounds to the bale" be replaced by the phrase "to correspond to the buyers' preference as to number per package."

G-1b. In view of wording recommended in G-1a, this paragraph may be deleted.

I. This section should be reworded to correspond to the above changes. Further changes will have to await the results of the tests being run at the University of Florida.

1-2g and -2h. In order to discourage violation of the "5 inch" law, "(3-inch)" should be replaced by "(3-inch cut sponge)", and the sentence giving designations in pounds should be deleted or replaced by one containing designations in perimeters of "sponge cuts."

11. The members voted unanimously that it be recommended that the "types" be rearranged and renumbered to give a more logical arrangement by source of the sponges, such as:

Domestic:

Type (--). - Rock Island ---

____

Type (--). - Sheepswool, Inshore ---

____

Type (--). - Yellow ---

____

Type (--). - Hudson Grass ---

____

Type (--). - Anclote Grass ---

West Indies:

Type (--). - Key West Group ---

____

Type (--). - Cuban ---

____

Mediterranean:

Type (--). - and so forth

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INT.-DUP. SEC., WASH., D.C. 45415

OBSERVATIONS OF MOULTING FEMALE KING CRABS *PARALITHODES CAMTSCHATICA*

SPECIAL SCIENTIFIC REPORT—FISHERIES No. 274

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

EXPLANATORY NOTE

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United States Department of the Interior, Fred A. Seaton, Secretary
Fish and Wildlife Service, Arnie J. Suomela, Commissioner

OBSERVATIONS OF MOLTING FEMALE KING CRABS (*Paralithodes camtschatica*)

by

Henry M. Sakuda
Fishery Research Biologist

Contribution No. 4 to research conducted with the approval of the United States Section of the International North Pacific Fisheries Commission. The Commission, established in 1953 by the International Convention for the High Seas Fisheries of the North Pacific Ocean, coordinates the research of the member nations: Japan, Canada, and the United States. The resulting investigations provide data to the Commission for use in carrying out its duties in connection with fishery conservation problems in the North Pacific Ocean. Publication of this scientific report has been approved by the United States Section of the Commission.

Special Scientific Report--Fisheries No. 274

Washington, D. C.

December 1958

The Library of Congress has cataloged this publication as follows:

Sakuda, Henry M

Observations of moulting female king crabs (*Paralithodes camtschatica*) Washington, U. S. Dept. of the Interior, Fish and Wildlife Service, 1958.

5 p. illus. 27 cm. (U. S. Fish and Wildlife Service. Special scientific report: fisheries, no. 274)

Includes bibliography.

1. Paralithodes camtschatica. I. Title. (Series)

SH11.A335 no. 274 595.3844 59-60427

Library of Congress

The Fish and Wildlife Service series, Special Scientific Report--Fisheries, is cataloged as follows:

U. S. *Fish and Wildlife Service.*

Special scientific report: fisheries. **no. 1–**

[Washington] 1949–

no. illus., maps, diagrs. 27 cm.

Supersedes in part the Service's Special scientific report.

1. Fisheries—Research.

SH11.A335 639.2072 59-60217

Library of Congress [2]

ABSTRACT

This report describes the observations of 9 molting mature female king crabs (Paralithodes camtschatica) caught in Pavlof Bay on the Alaska Peninsula between May 1 and May 18, 1957. Observations showed that the molting soft-shelled crabs emerge through an opening between the posterior margin of the carapace and anterior margin of the abdominal segments. The female crabs all cast their shells without the males being present. The remaining cast shells were intact, without breaks in the shell parts. The maximum growth of the newly molted crabs was attained 2 days after molting.

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OBSERVATIONS OF MOLTING FEMALE KING CRABS
(*Paralithodes camtschatica*)

INTRODUCTION

The Pacific Salmon Investigations of the U. S. Fish and Wildlife Service is conducting studies to determine the need for measures for conservation of the eastern Bering Sea king crab (*Paralithodes camtschatica*), as part of the research program of the International North Pacific Fisheries Commission. In this respect, knowledge of the biology of the king crab is essential.

Molting, an important phase in the life history of king crab as well as other crustacea, is a phenomenon whereby the exoskeleton is periodically discarded. Generally all the outer cuticular layers of the shell, eyes, antennae, gills, tendons, mouth parts, esophagus, and stomach with its chitinous teeth are replaced, leaving no apparent trace of this change. The age of the crab, therefore, is extremely difficult to determine. One of the methods of estimating age is to rear crabs in order to observe the molting frequency and measure the growth attained from molting. These measurements combined with those obtained by sampling the fishery then may give some indications of age.

This report describes the observations of nine molting female king crabs caught in Pavlof Bay on the Alaska Peninsula between May 1 and 18, 1957. Work was done aboard the MV *Deep Sea*, a king crab factoryship.

I am grateful to Wakefield's Deep Sea Trawlers Inc. and the crew of the vessel for their cooperation and the use of their facilities. My thanks also to Mr. Glen Davenport for his assistance, and Mr. T. O. Duncan for photographs.

PREMOLTING OBSERVATIONS

The annual molting and mating period of female king crabs occur in the spring. At this time the male is observed holding the meropodite of the chelipeds of the female with his chela. After the female molts, the male leaves the cast shell and resumes the original "hand shaking" position with the soft-shelled female. The female then lays new eggs which attach to the swimmerets in the abdominal pouch and are fertilized. Shell-casting, however, can take place without the male.

Upon capture, the crabs were placed in live boxes provided with running sea water. For identification each crab was marked with a number on the carapace before and after molting. Carapace length measurements and examinations were made daily from the time of capture until release.

The nine female specimens in a premolting condition had similar external characteristics. The shells of the carapace and appendages were thin and pliable. The membranes connecting the shell parts were also very thin and cellophane-like in texture. A slight pink color, differing from the opaque color found in crabs of nonmolting condition, was detected under the thin membranes at the joints of each leg and between the plates of the abdomen. On one specimen the suture along the anterior border of the first abdominal segment was split and the pink soft shell exposed. (See figure 1 for arrangement of the abdominal segments.) The eyes of the specimens were bright red in contrast to the brown colored eyes of nonmolting crabs.

Prior to molting, the female crabs were observed with their bodies lifted off the bottom of the live box. Their abdomens, extended away from their bodies, moved rhythmically back and forth exposing the swimmerets covered with empty egg cases. This behavior was seen frequently until molting and may be beneficial in releasing zoea larvae as well as loosening the soft shell from the old, making extraction easier during the shell-casting process.

MOLTING OBSERVATIONS

The first step observed in the shell-casting process was a separation in the thin membrane anterior to the first abdominal segment. (See figure 1 for arrangement of the membrane connecting the

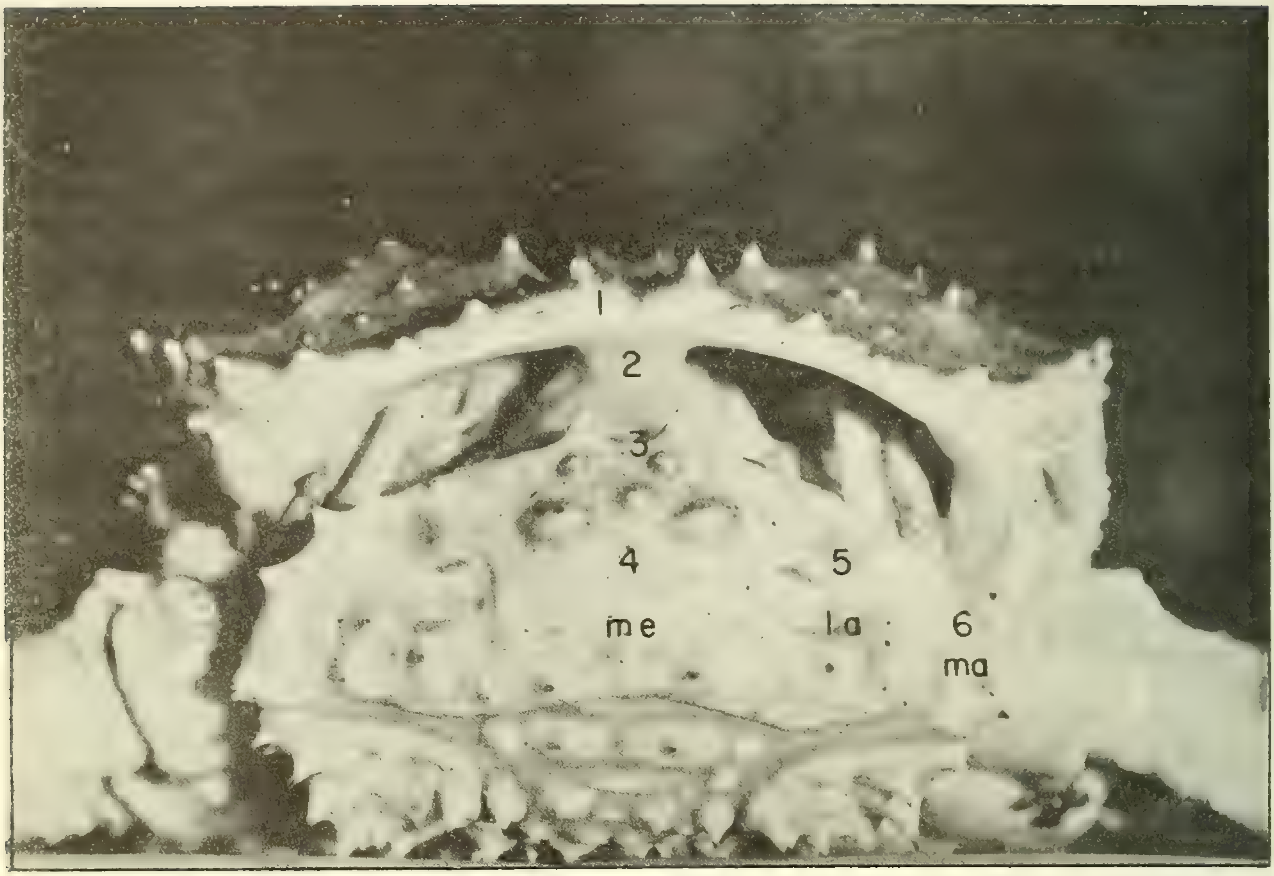

Figure 1.--Posterior view of king crab showing arrangement of carapace and abdominal segments. (After Marukawa, 1933.) 1, posterior border of carapace; 2, isthmus between carapace and body; 3, first abdominal segment; 4-6, second abdominal segments; me- median plate, la- lateral plate, ma- marginal plate.

carapace and abdomen). The carapace and abdominal segments then started to part, thus tearing the membrane further and opening a large gap. The tear in the membrane extended completely along the anterior margin of the abdominal segments, vertically up the isthmus between the carapace and body, and completely across the posterior margin of the carapace. As the membrane continued to tear, the opening grew larger and the soft-shelled crab backed out of the old shell. During the only occasion when a crab was timed casting its shell, four minutes were required to back out of the old shell.

Many females examined during trawling operations were found with the membrane along the first abdominal segment split and this section open.

POSTMOLTING OBSERVATIONS

Seven of the nine cast shells remained intact. The membranes connecting the sides of the carapace to the body shell did not separate (fig. 2), except for the section between the carapace and abdominal segments. In the other two, the thin membranes in other parts of the cast shells were torn and parts lost.

The outer layers of the antennae, eyes, gills, stomach, and mouth parts were entirely left with the old shells; the tendons of the legs were also left in the cast shells. One specimen sloughed off its left fourth leg at the basal segment and left it in the cast shell. This crab would probably regenerate a new leg.

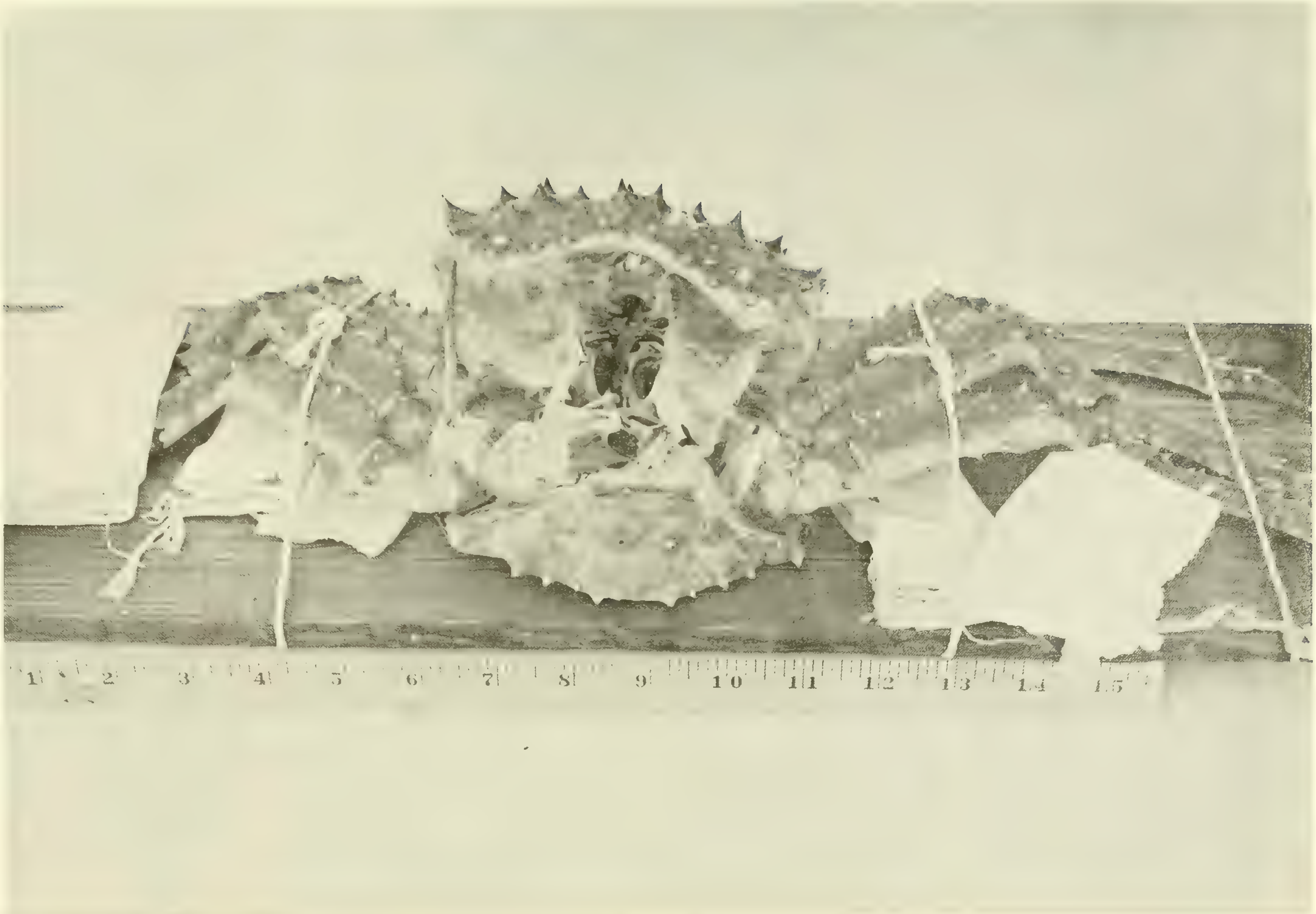

FIGURE 2:--Posterior view of intact cast shell of female king crab showing opening through which the crab emerges from the old shell.

The length measurements of the carapace of the newly molted crabs showed some fluctuations during hardening, which lasted from 3 to 4 days. In all cases, however, the specimens which were held from 5 to 13 days after molting showed the initial growth measured 2 days after molting to be the total growth. Growth from molting ranged from 2 to 6 mm., with an average of 4 mm. as shown in table 1 and figure 3.

Except for one specimen, all the newly molted females failed to lay eggs.

Wallace et al. (1949) states, "a simultaneous action is exerted by the tissue under the carapace, leading to breaks on the sides, posterior end, and, in some cases, entirely across the carapace. Very often the old shell is left completely intact except for the breaks along the sides of the carapace". In the present study seven of the cast shells remained completely intact, except for the torn membrane on the posterior end of the carapace. In all nine crabs the carapace and leg shells were not cracked.

Growth measurements from this study (fig. 3) agree closely with the growth of females from tagging and molting studies described by Wallace et al. (1949) and Stevens (1955). The 3 to 4 days taken for shell-hardening agrees with the average days required for growth and hardening mentioned by Marukawa (1933).

Wallace et al. (1949) states that female crabs allowed to molt in the absence of males do not extrude their eggs until permitted to mate. In this study, however, one of the nine females extruded eggs a day after molting.

SUMMARY

1. Before molting the females were observed rhythmically moving and stretching their abdomens.

2. The female crabs cast their shells without the males being present.

3. Most of the shells cast were intact except for the split in the membrane connecting the carapace to the abdominal segments.

4. One shell-casting process was timed at 4 minutes.

5. All but one of the newly molted females failed to lay eggs.

6. Size measurements fluctuated during shell-hardening; however, the growth measured 2 days after molting was the total growth.

7. The amount of growth ranged from 2 to 6 mm., with an average of 4 mm.

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Table 1.--Dimensions of nine molting female king crabs

No.	Original carapace length (mm.)	Carapace length at release (mm.)	Growth (mm.)	Days held from molt to release
1.	115	120.0	5.0	10
2.	118	121.0	3.0	13
3.	119	122.0	3.0	10
4.	120	122.0	2.0	13
5.	123	127.0	4.0	11
6.	127	132.0	5.0	7
7.	131	136.0	5.0	13
8.	131	137.0	6.0	5
9.	141	144.5	3.5	12

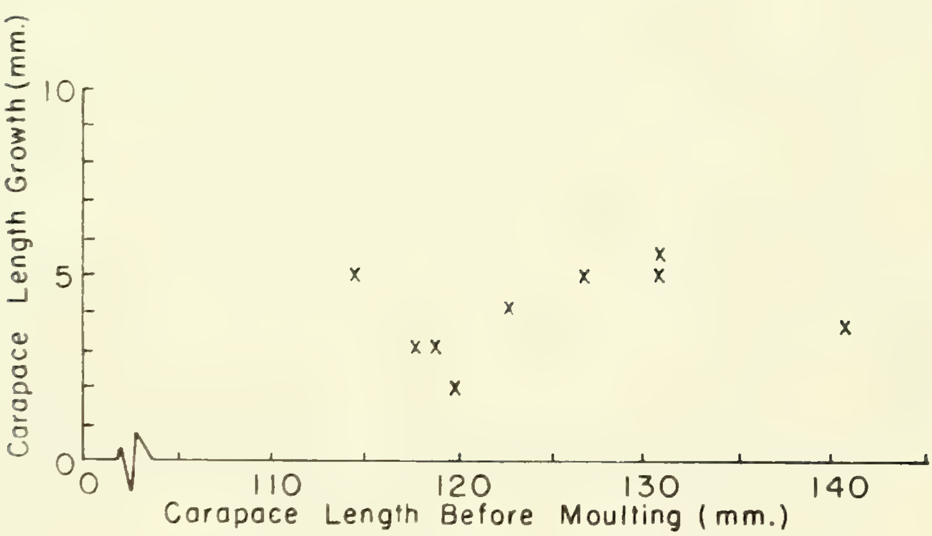

Figure 3.--Growth of nine female king crabs from molting.

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